CHAPTER 2

SAFETY CONSIDERATIONS IN PROCESS INDUSTRIES

OUTLINE

2.1 INTRODUCTION

- Workers in a factory, a manufacturing plant or a chemical plant remain exposed to moving conveyers, machines, dangerous chemicals, heat, pressures, high electric fields, accelerating objects and other sources of hazards.
- If workers are not protected from these hazards, there are chances of incidents to take place, which may result from a simple injury to death of a person.
- The damage can reach the whole manufacturing plant and its surrounding environment causing much loss of lives if the facilities or equipment are not controlled properly.
- For Example, On December 26, 1984 at 11:30 pm when people of Bhopal-India:
    - Leak of water into a storage tank containing methyl isocyanate (MIC) at the Union Carbide Plant.
    - About 40 tons of MIC poured from the tank for nearly two hours without any preventive measures being taken.
    - The night winds carried the MIC into the city of Bhopal. Some estimate that 4,000 people were killed, many in their sleep and as many as 400,000 were injured or affected.

- On April 26, 1986 at Chernobyl-Ukraine:
  - A nuclear reaction resulted in the explosion of one of the reactors in a nuclear power plant.
  - These reactors were constructed without containment shells.
  - The release of radioactive material covered hundreds of thousands of square kilometers.
  - More than 3-million people of the surrounding suburb suffered from this disaster. While 36 people died in the accident itself, the overall death total has been estimated to be 10,000 persons.
- On January 29, 2003, an explosion and fire destroyed the West Pharmaceutical Services plant in Kinston, North Carolina-USA:
  - Six deaths, dozens of injuries, and hundreds of job losses.
  - The investigators have found that the fuel for the explosion was a fine plastic powder used in producing rubber goods.
  - Combustible polyethylene dust accumulated above a suspended ceiling over a manufacturing area at the plant.

- These examples and others show that the causes of these incidents were not only due to ergonomic factor but also to the failure of the equipment or unknown reasons.
- The breakdown of these incidents was probably a lack of safety measures for the workers of the plants and also to the nearby people.

- The significance of safety measures is indicated
    - in the proper operation of the plant, its regular checkups, overhauling, repair and maintenance, regular inspection of moving objects, electrical appliances, switches, motors, activators, valves, pipelines, storage tanks, reactors, boilers and pressure gauges.

    - The proper training of workers for running the operations and dealing with emergencies, spills, leaks, fire breakouts, chemical handling and electrical shock avoidance should not be ignored.

2.2 OSHA and PSM (Occupational Safety and Health Act and Process Safety Management)

- The hazardous chemicals continue to pose a significant threat to workers at facilities that use, manufacture, and handle these materials.

- The continuing occurrence of incidents has provided the impetus for authorities worldwide to develop or consider the legislation and regulations directed towards eliminating or minimizing the potential for such events.

- By 1985, in the United States, Congress, federal agencies, industry, and unions became actively concerned and involved in protecting the public and the environment from major chemical accidents involving highly hazardous chemicals.

- The Environmental Protection Agency (EPA) was seriously involved in community planning and preparation against the serious release of hazardous materials.

- Soon after the Bhopal incident, the Occupation Safety and Health Administrator (OSHA) has determined the necessity to investigate the general standard of the chemical industry and its process hazards, specifically the employee protection from the large releases of hazardous chemicals.

- OSHA has introduced certain standards regarding hazardous materials, flammable liquids, compressed and liquefied petroleum gases, explosives and fireworks.

- The flammable liquids and compressed and liquefied petroleum gas standards were emphasized on the specifications of the equipment in order to protect employees from other hazardous situations arising from the use of highly hazardous chemicals.

- In certain industrial processes, standards do exist for employee exposure to certain specific toxic substances. They focus on routine and daily exposure emergencies such as spills and precautions to prevent from the large accidental releases.

- The objectives of the process safety management of highly hazardous chemicals were to prevent the unwanted release of hazardous chemicals especially into locations that could expose employees and others to serious hazards.
    - An effective process safety management requires a systematic approach to evaluating the whole process.
    - The process design, process technology, operational and maintenance activities and procedures, non-routine activities and procedures, emergency preparedness plans and procedures, training programs, and other elements that have an impact on the process are all considered in the evaluation.
    - The processes should be evaluated and strengthened to incorporate into the design and operation of the process the measures to prevent or mitigate the release of hazardous.
    - The process safety management is the proactive identification, evaluation and mitigation or prevention of chemical releases.
- These standards also target highly hazardous chemicals and radioactive substances that have the potential to cause a catastrophic incident.

2.3 Incident Statistics and Financial Aspects

- Normally the management of any production plant is not very concerned over the safety of the employee.

- The management should be informed about the loses of working hours, employee injuries, property damage, fires, machinery breakdown, public liabilities, auto accidents, product liabilities, fines and costly insurance and others.

- The varying estimates of the annual cost of industrial accidents are stated in terms of **millions of dollars** and are usually based on the time of the injured worker.

- This is largely an employer loss, but is far from being all of the cost to the employer.

- The remaining incidental cost is four times as great as the compensation and the medical payments.

2.4 Safety Decision Hierarchy

- The hierarchy identifies the actions to be considered in an order of effectiveness to resolve hazard and risk situations.

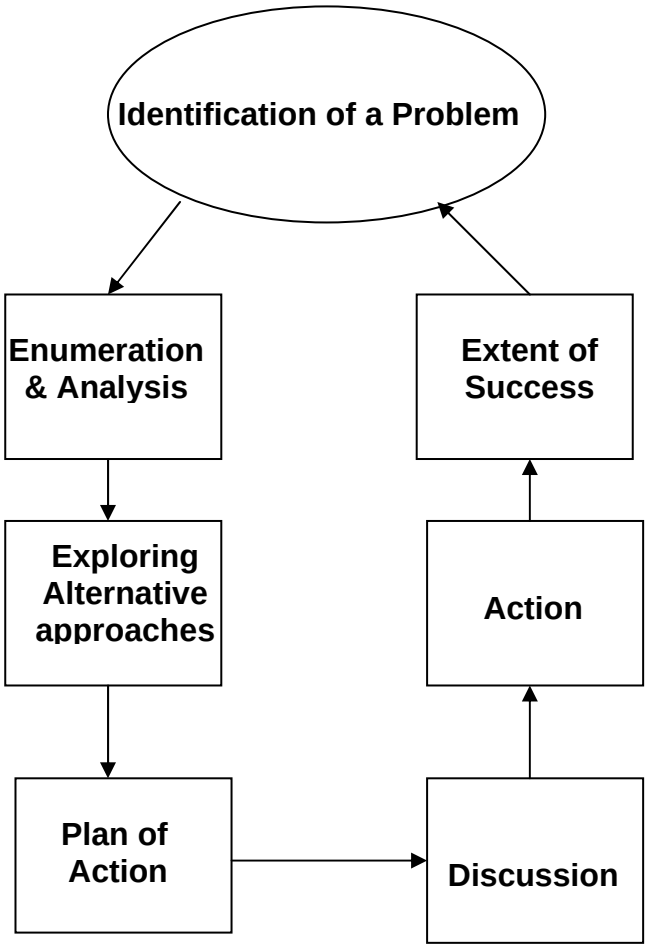

Figure 2.3. Risk Assessment Hierarchy

- The risk assessment hierarchy:

    - identify and analyze the hazard followed later by the assessment of the risk.

    - alternative approaches are carried out to eliminate the hazards and risks through system design and redesign.

    - the risk can be reduced by substituting less hazardous materials or by incorporating new safety devices, warning systems, warning signs, new procedures, training of employees and by providing personnel protecting equipment.

    - a decision is normally taken after the evaluation of the various alternatives followed by the reassessment of the plan of action.

2.5 Hazards Analysis and Risk Assessment (HARA)

- The job of making a guideline becomes more difficult due to the varied nature of different industries, e.g., machinery making, chemicals production, semiconductors, pharmaceuticals, pesticides, construction materials, petroleum and refinery, food and beverages. Each of these industries has its own hazards and risks.

- It is not possible to apply a general HARA plan to all of these industries. The main features:
  - ❖ Specify the limits of the machine.
  - ❖ Identify the hazards and assess the risks.
  - ❖ Remove the hazards or limit the risks as much as possible.
  - ❖ Design guards and safety devices against any remaining risks.
  - ❖ Inform and warn the user about any residual risks of the process or machine.
  - ❖ Consider any necessary additional precautions.

2.6 Types of Hazards in Industry

2.6.1 Heat and Temperature

- Sources of heat: boilers, kilns, incinerators, evaporators and cryogenic facilities.
- High and lower temperatures, heat and cold can directly lead to sources of injuries to personnel and also may damage the equipment.
- The immediate means by which the temperature and heat can injure the personnel is through burns, which can injure the skin and muscles as well as other tissues below the skin.
- The continuing exposure to high temperatures and humidity or to the hot Sun is a common cause of heat cramps, heat exhaustion or heat strokes.
- The same degrees of exposure may produce different effects, depending on the susceptibility of the person exposed.
- High and low temperatures affect the personnel's performance. The stress that was generated by high temperature may degrade the performance of the employee.
- The intensity of heat, duration of the exposure period, task involved, personal physical conditions, and other stresses like humidity and hot wind are also important factors.

- There is a report indicating that the performance at high humidity is twice lower than at high temperature.

- Long exposure to high temperatures does affect the human performance.

- The effects of heat and temperature do not only affect the workers but also the equipments and the process. For example, certain chemicals have a low boiling point and increased temperature can cause an explosion.

- The effect of excessive heat results in the degradation of the equipment by corrosion and weathering of polymer and plastic materials used in the plant. The corrosion reactions are very rapid at elevated temperatures.

- The reliabilities of electronic devices are also degraded at high temperatures.

- The increase pressure of the gas in a closed container at high temperature can cause rupture of a tank.

- A liquid may also expand on elevated temperature. An overflowing flammable liquid would then generate a severe fire hazard.

2.6.2 Pressure Hazards

- Work at lower pressure can avoid serious injuries and damage.

- It is also commonly and mistakenly believed that injury and damage will result only from high pressures.

- Example: the damage caused by a slow moving hurricane or wind blowing at 70 miles per hour is enormous. Nevertheless, the expansive pressure exerted is in the range of 0.1-0.25 psi. Therefore, high pressure is a relative term.

- The pressures of boilers, cylinders or compressors can be categorized in the following classes:

Low pressure	1 atmosphere (14.6 psi) to 500 psi
Medium pressure	500 to 3,000 psi
High pressure	2000 to 10,000 psi
Ultra high pressure	above 10,000 psi

- The rupture of a pressure vessel occurs when the total force that causes the rupture exceeds the vessel's strength.

- The possibility of a rupture because of over pressurization can be minimized by providing safety valves.

- Possible discharges from such valves should be conducted to locations where they constitute no danger, especially if the fluid discharge is very hot, flammable, toxic or corrosive.

- Storage tanks and fermenter reactors should be pressure and temperature controlled.

- The high pressure vessels should not be located near sources of heat, such as radiators, boilers, or furnaces, or if in an open area they should be covered.

- Vessels containing cryogenic liquids can absorb heat from the normal environment that could cause boiling of liquids and very high pressures.

- The pressures in cylinders of compressed air, oxygen, or carbon dioxide are over 2000 psi. When these cylinders weigh about 200 pounds, the force or thrust generated by the gas flowing through the opening when a valve breaks off a cylinder can be 20 to 50 times greater than their weight.

- Accidents have occurred when such cylinders were dropped or struck so that the valve breaks off.

- These cylinders sometimes took off, smashing through buildings, machinery and injuring personnel nearby.

- Safeguards should be used while handling, transporting and using these cylinders.

- Whipping of flexible gas lines can also generate injury and damage. All high pressure lines and hoses should be restrained from possible whipping by being weighted with sand bags at short intervals, chained, clamped, or restricted by all of these means.

- Workers should be trained to never attempt to grab and restrain a whipping line.

- A vacuum (the negative difference between atmospheric and below-atmospheric pressure) can be as damaging as the high pressure systems. Sometimes a vacuum is more damaging to the structures, which may not be built to withstand reversal stresses.

- Most buildings are designed to take positive load but not to resist negative pressures.

- Such negative pressures might be generated on the lee side (the side opposite from the direction the wind blows) when a wind passes over.

- In most cases, the damage done by the high winds during hurricanes or tornadoes is due to a vacuum.

- The negative pressure can also be generated by the condensation of vapors, which could cause a collapse of the closed containers.

- When vapors are cooled down to liquefy, the volume occupied by the liquid is far less than their vapors. As a result, the partial pressure inside the container decreases significantly.

2.6.3 Electrical Hazards

- Electrical power is beneficial and at the same time it is hazardous if not properly used. The hazards involved are mainly:

  (i) Shock to personnel

  (ii) Short circuiting and overheating

  (iii) Ignition of combustible materials

  (iv) Electrical explosions

  (v) Inadvertent activation of equipment

  (vi) Electromagnetic effects on equipments and personnel.

- The damaging factor and the chief source of injury and death in electrical shock is the current flow. Current in the range of 1-75 milliamperes are not damaging but above this range can be fatal.

- The equipment failure causes an open and short circuit, static electrical discharge and by lightening strike.

- Accidents are frequent when a person is electrocuted due to the lack of care near the energized bare conductor, the construction area, rooftops, T.V. antennas, or working on live high voltage lines.

- Accidents may occur if a circuit is opened when an electrician begins work or if a person reenergizes the circuit by mistake.

- Electrical circuit shut down for repair or maintenance should be locked and tagged out after being de-energized. The circuit, which uses capacitors, should be discharged first by grounding.

- Line equipment is normally insulated but with time the insulation deteriorates due to many factors such as heat, elevated temperature, moisture and humidity, oxidation of insulators, chemical incompatibility, mechanical damage, high voltages, and photochemical reactions. If the insulation is defected due to deterioration or damage, a person could be electrocuted.

- Equipment failure is another cause of electrical shock. Some examples include leakage in washing machines, electrical irons, water pumps, broken energized power lines, grinding and drilling machines. The equipment must be grounded with three wire cables.

- The shock protection by these sources can be avoided in the following ways:
    - enhanced insulation of wires and equipment,
    - insulation of a person who is working on a power line.
    - Electrical equipment can be isolated. These should be properly marked by warning signs of high voltage and electrical shock.

- Static charge is another hazard for electrical shock. Whenever there is an excess or deficiency of electrons on moving objects, it causes a potential difference between them. For example, a person moving on a carpet or a conveyer carrying materials that may generate static electric charge can cause a simple electric shock.

- There are ways of controlling the static problems. The person working in an oil refinery or in a gas station can be asked to ***wear cotton clothing*** instead of nylon or wool.

- Equipment can be sprayed by a conducting material to avoid the charge generation. Electroneutralization can generate high voltage. As a result, a gas ionizes and produces positive and negative charge species which combines the opposite charges and neutralizes them. Raising the humidity above 65% permits the static charge to load off and dissipate.

- Lightning is a massive, natural discharge of static electricity involving very high potential and high current flow. Lighting follows the path of least resistance to earth, high mountains, tall trees, T.V. antennas, light arrestor, rods and grounds provide the paths.

- Lightning rods, multiple-point discharge rods, and lightning warning are now used as protective devices.

- The lightning warning devices can detect lightning in a waste area and can be coupled with protection units. All overhead power-lines are equipped with these lightening warning devices.

- Keeping sparks and arc away from combustible materials or chemicals can provide the protection from electrical hazards.

- It is also advisable to eliminate all electrical equipment from hazardous areas in which a flammable atmosphere might exist.

2.6.4 Mechanical Hazards

- Most of the injuries in industrial plants are originally from mechanical causes.

- These industrial plants have belt-driven rotating equipment, open geared power-presses, power hammers, cutter conveyers, kilns and incinerators.

- These different kinds of mechanical equipment are used in industrial plants and each has its own mechanical hazards including cutting, tearing and breaking.

- A person working in a paper plant at a manually fed paper cutter may have chances of cutting skin or body parts.

- The sharp edges of the equipment and poor finishes are sometimes major causes of cutting. The equipment must be designed in such a way that they should not have sharp edges and poor finishes.

- Shearing will occur when a sharp edge is in a linear motion in a direction vertical to the line of the edge. Examples include powered paper cutter and metal plates. The effect of the shear can be fatal to the person working at the machines, which can cause amputation.

- An impactor can crush the muscle tissues or any part of the human anatomy. Sometimes two rotating objects can cause crushing of the body part when they are moving towards each other.

- Common examples include meshing gears, belts running over pulleys, cables on drums, chains on sprockets, rollers on manual type washing machines, and rolls on rubber mills or paper calendars.

- Normally a guard is provided to a moving part of the machine, which is a barrier that prevents the entry of any part of the human body in the hazardous area.

- A safety device can be installed which prevents or interrupts the operation, if part of the operator's body is within a hazardous area or requires its withdrawal prior to machine operation.

- The guard or safety device must not constitute a hazard itself, must be safe, less maintenance demanding, easy to use, automatically controlled or fixed on the machines.

- Total enclosure is represented by fixed covers over the pulleys, gears, shafts and couplings to prevent access to the hazardous area. They can also be coupled with interlock devices for shutting down the machine if a portion or the whole cover is removed.

- Moveable barriers or gates can also be provided which open and close easily for loading and unloading materials. Double control devices that are operated by dual switches far apart cannot be operated by a single hand.

- Mechanical feed is provided by a mechanical feeder, in which a processing material is placed over a feeding device. There are certain safety devices like the optical sensors, which monitor the light intensity of a reference source.

2.6.5 Toxic Materials

- Highly reactive chemicals are being used more frequently in industries, agriculture, research and defense.

- Many of these chemicals are found to be carcinogenic, teratogenic and a cause of long lasting injuries.

- There is a need to understand the ways by which these chemicals enter the human body and their physiological effects to the tissues. The preventive measures should be exercised to avoid this absorption.

- A material is considered toxic when a small quantity will cause injuries to the body of an organism. Almost all materials are injurious to health but at different levels.

- The oxygen we breathe can be dangerous if taken at 100% without dilution.

- The nitrogen and carbon dioxide can be dangerous although they are present in the air and lungs at high concentrations.

- The concentration or the toxicity level of the substance is not the only factor of a toxic chemical. The susceptibility of the human body to toxic chemicals and their concentrations varies.

- The other factors, which affect the severity of the injury, are the concentration, duration of exposure, the route, and the temperature.

- The toxic materials may be solid, liquid or gas. The solid toxic materials are radioactive substances and metals such as Pd, Cd, As, Cr, Al and others in various forms.

- The chemicals are mostly in liquid and gaseous forms. For example, diethyl bromide, chlorofluoro carbons (CFCs), trichlorethane or trichloromethane are liquids while phosgene, chlorine, carbon monoxide, hydrogen cyanide and isocyanate are gases.

- What happens in an industrial plant when a leak of some toxic gases like isocyanate, ethane or others occurs?
  - The concentration of these gases in air increases while the concentration of oxygen decreases.
  - The worker feels suffocation or asphyxia.

- The concentration of carbon dioxide increases as a result blood carbonic level increases, which lowers further the concentration of oxygen.
- The worker undergoes a condition of hypoxia (hypo: below; oxia: oxygen). The effect of hypoxia includes loss in perception, decrease in the brain activity, unconsciousness, and deep breathing. It may lead to irreversible damage to brain, paralysis and ultimately death. Some gases alter the oxygen carrying cells in the blood (hemoglobin).
- For example, the exposure to carbon monoxide (1-1.5%) decreases the oxygen carrying capacity of blood, which results in hypoxia.
- Some chemicals like nitrates, nitrites or other oxidizing agents are also harmful to the human body.

- It may also cause the inflammation of skin, eyes, and respiratory tracts. Even a small amount of irritant can cause physiological injury to an extensive area of tissue.

- Ammonia, acrolein, hydrazine and hydrofluoric acid, fluorosilicic acid, and asbestos can cause injuries to the upper respiratory tract, while chlorine, fluorine, ozone, nitric acid and nitrogen tetroxide affect the lower portion and the alveoli.

- Some chemicals are carcinogenic (cancer producing). For example, bitumen, mineral oil, aromatic compounds, vinyl chloride, benzidene, biphenyl pyridine are the known carcinogen and their use is eliminated or replaced by non-carcinogenic chemicals.

- Asbestos is a particulate matter that causes asbestosis and cancer of lungs, colon, rectum and stomach. Therefore, OSHA has imposed a ban on zero fiber or particulate matter in the working environment.

- All industrial plants are obligated to observe criteria stipulated in OSHA standards, which include the exposure to different chemicals and their threshold limit for industrial workers.

- Personnel Protective Equipment (PPE) must be used for protection from toxic gases and vapors.

- Safety respiratory protective equipment is required for normal hazardous operations like working in a spray painting plant, production and utilization of toxic chemicals, and fumigant utilization.

- There are two types of respiratory protective equipments:
  (i) Air Purifier: The contaminated air is purified by chemical or mechanical means. For example, the removal of organic vapors and acidic gases, ammonia, carbon monoxide and carbon dioxide is done over charcoal, silica gel, hopocalite [MnO_2:CuO (60:40%)] and soda lime, respectively.
  (ii) Oxygen Breathing Apparatus: The portable equipment which supplies oxygen for respiratory needs is called an oxygen breathing apparatus.

- Special protective clothing should be provided to the working personnel for protection from toxic chemicals. The clothing is made from materials resistant to acids, bases, toxic chemicals and even for high temperatures and the possibility of an outbreak of fire.

- On an operational plant there is a need to mark the container containing chemicals with proper labeling. These chemicals and hazards have been categorized into different classes. Different colors were assigned depending upon their physical or chemical hazards.

- According to this classification an inflammable liquid or solid chemical is given a number designating its class and a red color, which indicates its physical or chemical hazard like flammability.

- For toxic, corrosive, explosive radioactive material a container should be marked with different numbers and colors.

Table 2.1. Classes of Hazard Materials and their DOT symbols

Hazard Class	Color	Symbols
Class 1: Explosives	Orange	Exploding Device
Class 2: Gases	Yellow	Burning "O"
	Red	Flame
	White	Skull and cross bones
	Green	Cylinder
Class 3: Flammable Liquids	Red	Flame
Class 4: Flammable Solids	Red/White Stripes	Flame
	Red/White /field	Flame
	Blue	Flame
Class5:Oxidizers/Organic peroxide	Yellow	Burning "O"
Class 6:Poisons/Etiologic agent	White	Skull and cross bones
	White	Sheaf of wheat with cross
	White	Broken circles
Class 7: Radioactive	Yellow/White field	Trefoil/spinning propeller
Class 8: Corrosive	Black/White Field	Melting metal bar and hand
Class 9: Miscellaneous	Black Stripes, White Field	Black and white stripes

Figure 2.4. Symbols and their color as recommended by the Department of Transportation

- The personnel should be informed and trained on the significance of these numbers and colors and how to handle these chemicals to avoid any incident.

2.6.6 Fire and Explosion

- Fire and explosion are the common incidents in many chemical industries.

- A fuel, an oxidizer and a source of ignition are required to start a fire. However, fire and explosion take place only when there are appropriate conditions for it.

- Many types of fuel and oxidizers are available in any industry. There are three types of fuel. They are mainly solids, liquids or gases.

- The chemicals that are used as cleaning agents or solvents act as fuels. Lubricants, coatings, paints, industrial chemicals, refrigerants, hydraulic fluids, polymer plastics, and paper wood cartons are potential fuels.

- The next element for fire is an oxidizer. The most common oxidizer is the oxygen in air, which helps in oxidizing the fuel. Sometimes a chemical can be self ignited in the presence of an oxidizer.

- For example, white phosphorus catches fires as soon as it comes into contact with air. Pure oxygen is a strong oxidizer. When a slight leak is present in an oxygen cylinder a dangerous fire hazard may exist.

- Fluorine is another strong oxidizer. It can react with moisture in air and catch fire. It is normally used diluted with nitrogen.

- Other oxidizers include chlorine, halogenated compounds, nitrates, nitrites, peroxides and acids.

- These oxidizers should be handled with care and their contact with fuel should be avoided.

- The source of ignition consists of materials that may initiate a fire on friction. The igniter may be sunlight, an arc or an electrical spark.

- The common sources of electrical ignition in an industrial plant are the sparks of the electric motors, generators or electrical short circuits, arcing between contacts of electrical switches or relays, ….

- The sources of other igniters are hot plates, hot moving parts of some instruments, engines, radiators, overheated wiring, boilers, metals heated from the friction, metal being welded or sometimes a cigarette…

- The fires can have tremendous effects on human live and the immediate surroundings and even on the environment.

- Fire produces carbon monoxide, carbon dioxide, solid carbon particles, and smoke. Death may occur as the concentration of the oxygen in air decreases in case of fire.

- In any industrial plant, there are devices installed to detect any kind of fire, smoke, or heat.

- There are fire detection instruments including thermo sensitive switches, thermo conductive detectors, radiant energy detectors, gas detectors, or ionization detectors.

- The suppression of the increasing fire can be carried out by various methods.

- The very first method is the isolation of the fire which means to cut the supply of fuel to the fire. Fire suppression can also be achieved by blanketing a fire or by covering it with inert solid, foam, thickened water or cover it with nonflammable gas such as CO_2.

- The other available method is the dilution of the fuel, if it is a liquid fuel, by adding noncombustible liquid into it and, if it is a gas, by adding nonflammable gas.

- Fire is a chain process. It can be stopped by breaking this chain. Scavengers are used to stop the free radical chain reactions and subsequently the fire is extinguished. Halogenated compounds are usually good chain reaction inhibitors.

- When fire is ignited due to fuel and there is ***no electrical hazard*** nearby, water is used as a fire suppressant.

- Water is not recommended for sodium or magnesium metals.

- Water can also be used as diluents and stop chain reactions.

- Sometimes thickening agents are added to the water to increase the residence time of water and its effectiveness. The thickening agents such as clays, gums, and sodium and calcium borates are used in forest fires.

- The chloride of calcium and lithium depress the freezing point to -40°C. The salts of potassium carbonate deposited on burning materials or the gas produced act as fire inhibitors.

- Gas extinguishers may be used for enclosed spaces. Carbon dioxide (CO_2) is widely used as a fire extinguisher. When carbon dioxide is sprayed on fire it emerges as snow and lowers the temperature.

- Halogenated hydrocarbons act solely by inhibiting chain reactions. The nature of the halogen is very important. The less reactive would be the best fire extinguisher. However, the problem with these halogenated compounds is their toxicity which limits their use.

- Foams are also used as fire suppressants. They suppress fire by cooling, blanketing, and sealing the burning fuel from the surrounding atmosphere. They are not suitable for gaseous fuel and fuel which reacts with water.

- Solid extinguishers such as sand or clay are also used to cover the oil or greases under fire. Sodium and potassium bicarbonate are also used as solid extinguishers for liquid fuel. They act as chain reaction inhibitors. At high temperatures, they decompose to give carbon dioxide which itself is an extinguisher that suppresses fire.

- Fire extinguishers are available which work automatically. They sense temperature, gas or fumes and start sprinkling the extinguishing materials (CO_2 or others).

- There are other portable units available which are marked, A, B, C depending upon the class of fires to be extinguished.

2.6.7 Accelerator and Falling Objects

- Most of the incidents occurred in an industrial plant are due to accelerator falls or falling objects.

- Data have shown that the non fatal occupational injuries and illnesses involving the days away from work are more than 60% to the total accidents.

- It was observed that a good number of workers fell down to lower levels in the fields of construction, cleaning of chimneys, and towers. Injuries also occurred when workers slipped and fell when working on the same level.

- Workers have been killed when they have struck their heads in falls from upright positions on slippery floors.

- During the construction and maintenance of bridges or elevated structures numerous falls of industrial workers into water occurred. These have resulted in various kinds of injuries such as spinal injuries, bleeding of lungs, shock and sometimes death.

- The main task is to determine the measures that should be taken to prevent these kinds of accidents.

- The best way to prevent a fall is by providing safeguards. Workers working at an elevation should be provided a safeguard net and fences. They may be tied with ropes as well.

- The mental and physical fitness of the workers should be checked regularly to determine whether they can work at elevations and can sustain vertigo (balance).

- The workers, which are not properly trained, should not be allowed to work on elevated sites. The workers can be provided with emergency nets, coiled knotted ropes, ladders, fire escapes and parachutes.

2.6.8 Confined Space

- A space large enough for an employee to enter and perform work with restricted activities or movement may contain a hazardous atmosphere.

- The different kinds of confined spaces for a worker in a plant are tanks, silos, storage bins, vessels, big fermentor, multieffective evaporators, boilers and wells.

- The permit-required confined space which contains a hazardous atmosphere includes chemical sludge, sewage, flammable gases or vapors, combustible, low oxygen concentration and higher carbon monoxide and carbon dioxide concentrations.

- Any recognizable environment and conditions which can cause a death, incapacitation, impairment of ability to rescue, injury or acute illness is permit-required confined space.

- The confined space may have a liquid, or finely divided solid substance that can be aspirated to cause the plugging of the respiratory system, or exert enough force to cause death by strangulation, construction or crushing.

- The atmospheric hazards are due to the presence and absence of certain gases, the presence of flammable and toxic vapors. There are three types of confined spaces:

  Class A: Immediately dangerous to life which contains oxygen: 16 % or less or greater than 25 % and flammability of more than 20 % and the toxicity is very high.

  Class B: Dangerous but not immediately life threatening having oxygen >16 to 19.4 % and from 21.5 to 25 %, flammability of 10 to 19 % and the toxicity is greater than the contamination level.

  Class C: is potential hazard to life having oxygen 19.5 to 21.4 %, flammability <10 % and the toxicity is less than the contamination level.

- The chemical release into a confined space is life threatening. High pressure liquid, falling objects, slippery surfaces in a confined space are all potential hazards.

- The limited space, inadequate ventilation and light, excessive noise are also physical hazards that increase the confined space hazards. The chemical waste and useful chemicals are also life threatening.

- There should be a thorough program for a confined-space working. The main points of program are as follow:
  - Identification and evaluation with respect to hazards of all confined spaces at the facility.
  - Posting a warning sign at the entrance of all identified spaces.
  - A job safety analysis for each task to be performed at confined spaces like, entry plan, assigned standby persons, communication between workers, rescue procedures and specified work procedures.
  - Testing and monitoring air quality in the confined space such as oxygen level, toxicity level, flammable materials, air pressure, and air contaminants.
  - Preparation of confined space like isolation, lockout, tag out, purging, cleaning and ventilation, special equipment and tools if required.
  - The use of personnel protective equipment to protect eyes, ears, hands, foot, body, chest and respiratory protections, harness, and mechanical lift-devices.

2.6.9 Radiation

- Light is comprised of a spectrum of wavelengths which consist of high energy cosmic rays, ultraviolet rays, visible light and low energy, infrared rays, micro and radio waves.

- The radioactive elements consist of alpha particles (helium nuclei), beta particles (positron), neutron and gamma rays. X-rays are also emitted by elements when high energy electrons strike a metal.

- The high energy of the X-rays and gamma rays make them more penetrating. Beta rays have less energy than the gamma ray and hence less penetrating.

- Alpha, beta, x-rays and gamma ray are ionizing radiation. These may cause injury by producing ionization of cellular components leading to functional changes in tissues of the body.

- The energy of these radiations is great enough to cause ionization of atoms that make up the cells, producing ion pairs, free radicals, and oxidation products. The damage to the cell is mostly irreversible.

- The radioactivity does not lose its potency by absorption or ingestion by living tissues.

- X-rays, gamma and cosmic rays are similar except gamma and cosmic rays are natural. These radiations are of very high energy and therefore more penetrating. They cause injury to whole body tissue. Therefore, they are more damaging to the living tissues.

- There are certain factors, which affect the exposure and risk. These are strength of the source, type of radiation and the distance.

- The energy order with respect to decreasing hazards is cosmic, gamma, x-rays > beta > α-particles.

- The sources of ionizing radiation are nuclear power plant, nuclear material processing and radionuclide generation for nondestructive purposes.

- Medical and chemical laboratories use these radionuclide, e.g. iodine, thallium and barium as tracers.

- The danger of mishandling these materials could cause release of these materials into the environment.

- Other than medical diagnostic tests for fracture of bones and constriction of blood vessels, these are used for the treatment of cancers.

- The precautionary and preventive measures include:
  - ❖ Well trained personnel should be allowed to work, use, operate, handle and transport these materials.
  - ❖ Safety Engineers should inspect any facility producing radiation, its protective devices and worker's protection prior to start.
  - ❖ Access to these areas should be restricted and only authorized person should be allowed.
  - ❖ Suitable warning signs should be posted in the ionization equipment area.
  - ❖ Emergency drills should be performed regularly.
  - ❖ All instruments that use radioactive sources should be kept in a shielded enclosure and made up of lead containing glasses, sheets and bricks which attenuate the radiation to a permissible level. Radiation going outside the area should be continuously monitored.
  - ❖ Every personnel should be given a dosimeter or film to estimate his or her absorbed radiation and a record should be maintained.

- ❖ Keep the exposure time for personnel as low as possible.
- ❖ The vital parts of the body should be protected by protective clothing, glasses, gloves, masks, and shoes.
- ❖ Drinking, eating, and smoking in that area should be prohibited.
- ❖ Cleanup of any spill should be performed with the help of safety engineers, which includes complete prevention of the spread, complete cleaning of the spilled area and a thorough decontamination of the contaminated personnel.

- The non-ionizing radiations are ultraviolet, visible, infrared, and microwave. The ultraviolet is the most dangerous radiation.

- The danger of the ultraviolet light is burning of the skin and blindness to the eye. The redness of the skin is often observed in the sun.

- To avoid these radiations, glasses with a face UV blocker and protective coats should be wearing. Goggles made of glass containing iron are more absorbing than simple glass, while Quartz is non-absorbing to UV radiation.

- Visible radiations are less harming. Simple protection from visible light is beneficial. Infrared radiations are heat radiation.

- The microwave radiation emitted by dryers, oven and heaters is normally used at home.

- The high-power radars used for military purposes, communication equipment, alarm systems, signal generators are other sources of microwave radiation.

- The low-power microwave radiation can cause heating and skin redness while high power can cause inductive heating of metals and induced currents that can produce electric spark.

- Rings, watches, metal bands, keys, and similar objects worn or carried by a person in such a field can be heated until they burn the bearers.

- The high power microwave antenna should not be inspected when energized or directed towards inhabited areas.

- Flammable materials stored in metallic containers should not be left in microwave induced magnetic fields. A warning device should be provided on microwave equipment to indicate when it is radiating.

- The radio frequency (RF) is another kind of radiation which is used in radio, television, satellite and mobile communications. The frequency radiated by these generators ranges from 3 KHz to 300 gigahertz.

- The increasing use of mobile phones may have resulted in cases of brain cancer. Experiments are under way to assess the damage caused by mobile phones to the brain.

- Experiments are also in progress to assess the safe range of the broad spectrum of radio waves. The most restrictive limits occur between 30-300 MHz where whole body absorption of RF energy is most efficient.

2.6.10 Noise and Vibrations

- Vibrations, sound and noise are other examples of common industrial hazards.

- The most common injury due to vibration is sound-induced hearing loss.

- The vibrations of machines, high-speed pumps, generators, boilers, and conveyers produce unwanted sound “noise”.

- The adverse affects produced by these sounds are as follows:
  - Loss of hearing sensitivity
  - Immediate physical damage (ruptured ear drum)
  - Interference resulting in the masking of other sound
  - Destruction
  - Annoyance
  - Other disorders such as tension and mental fatigue.

- A normal human can hear a sound ranging from 20 – 20,000 hertz.

- The general loss to hear the frequency range of 200 – 5000 hertz is compensable under the Worker’s Compensation Act.

- Degradation of hearing can also result from aging, long-term exposure to sounds of even moderately high levels or a very high intensity noise.

- Much of this degradation with age may be due to continuous exposure to environmental noise of the modern society rather than to simple aging. Hearing losses can occur even at noise levels lower than those permitted by

Table 2.2. Permissible Noise Exposures for Workers as Described by OSHA

Duration per day (hours)	Sound level (dBA)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25	115

- OSHA has estimated a safe maximum noise level of 85 decibels.

- The time-weighted average (TWA) is an exposure for an 8-hour to a noise level not exceeding 90 decibels.

- If this level exceeds 85 dBA, OSHA requires the employer to institute a hearing conservation program (HCP).

- Companies should attempt to reduce noise to the lowest possible level (< 80-dBA).

- The hearing conservation program (HCP) includes recording and categorizing the audiometric testing, monitoring of noise exposure, use of hearing protection devices (HPD), employee's training and noise control engineering.

- Exposure monitoring is another element of HCP. The sound level and exposure time should be measured.

- There are other instruments used for measuring noise including weighted-sound-levels and octave-band analyzers. These instruments measure the noises of different frequencies.

- Ear protection can be carried out naturally and by using hearing protection devices.

- Personnel protection devices must be used to protect the ear in an industrial plant. These are earplugs made up of rubber or plastic, which fit snugly in the ear canal without discomfort and effectively protect the ear.

- There are helmets available, which have noise attenuating electronic components and communication features.

2.6.11 Ergonomics (Human Factors)

- This is to evaluate personnel capabilities and to improve human safety, comfort and productivity in the workplace.

- The work related musculoskeletal disorders (WMSD) are the results of ergonomics and limitations of the human body for a sudden change or continuous working on a physical job.

- Efforts should be made to identify workers' complaints of undue strain, localized fatigue, discomfort, or pain that does not go away after overnight rest.

- Job testing which requires repetitive and strenuous exertions, frequent, heavy or overhead lifts, awkward work positions or the use of vibrating equipment should be identified along with WMSD risks.

- Human factors should be an important part of company's safety and health program.

- There are three types of control: likely engineering control, administrative and use of personal protecting instruments.

- The design or redesign of the job changes in a workstation layout, selection and use of other tools, and work procedures to take account of the capabilities and the limitation of the workers.

- Administrative control deals with the change of job, modified rules and procedures, scheduling more rest breaks, ample supply of personnel protective equipment.

- Use of various kinds of braces to protect from stress and strain and the rotation of workers on physically tiring jobs.

- In addition, the workers should be well trained to recognize ergonomics risk factors and techniques to reduce stress and strain while working on certain instruments.

- Regular health checking of the worker can help in early detection and prompt treatment for stress. Medical care should be provided for any damage to the employee.

2.7 Risk Management Plan

2.7.1 The Role of the Safety Personnel

- The problems were arose when the laboratory equipment and processes were transformed into industrial equipment.

- The hazardneous and the toxicity of chemicals, high temperatures, and pressures were tackled initially by chemists and engineers.

- Prepare trained personnel to take care of the hazards related to a particular process and the precautionary steps that should be taken to avoid them.

- The job of safety personnel is much diversified and is of high skill. He must be a knowledgeable in a wide range of technical, legal and administrative activities.

- A safety professional should be knowledgeable in depth in all areas of accident prevention and capable of solving problems that may arise.

- The safety personnel should be qualified by passing certain examinations and should be a certified safety professional.

- Graduate engineers that have achieved this rating by showing their knowledge in safety and accident prevention can work as safety plant engineers.

- Other certified personnel are certified product safety professionals, certified industrial hygienists, certified professional agronomists, and certified hazard control managers.

- A group of consultants may be needed to review the plants and determine their compliances with OSHA and others prevailing standards of the country.

- A second group may be knowledgeable in specific areas, such as flammable gases, toxic chemicals, explosives or mines.

- The protection of personnel safety comes first followed by the protection of the environment.

- This protection includes the prevention of leakage or release of liquids, oil, chemicals, detergents, or noxious gases, metals, complexes deleterious substance and even genetically modified organisms (GMO) in the environment.

- Protection against damage to the environment comes right after protection of personnel and animal before prevention of damage to equipment. Priority for rescue of equipment is last.

- The new concern of safety engineers is the area of accidental in-process damage or loss. Avoidance of such damage usually has been the responsibility of the production manager or staff.

- Lack of a simple feature, protective device, pressure regulator, auto-trip systems, are increasingly being addressed.

- Failure of a component of a process might cause failure in the assembled product.

- The expertise of a safety engineer can be beneficially applied to product safety.

2.8.2 Personal Protective Equipment (PPE)

- The most common use of personal protective equipment is for the protection of head, eyes, ears, torso, hands and feet.

- These equipment help to protect a person from many damages normally encountered in an industrial plant.

- PPE includes devices and clothing designed to be worn or used for the protection or safety of an individual in potentially hazardous areas or performing potentially hazardous operations.

- PPE should be used as a compulsory part of safety program and should not be considered as a substitute for engineering control or work practices.

- The basic elements of a safety program for PPE should be in-depth evaluation of the equipment needed to protect against the hazards at the workplace. The employee should be trained for using this equipment.

- The duty of the employer and safety personnel is to assess the chances and kinds of hazards that require the use of PPE.

- The head protection is an important factor where injuries are caused by falling or flying objects, or working below other employees who are working with tools that could fall down.

- A helmet does resist penetration and absorb the shock of a blow. The helmet consists of a hard shell and an inner lining to absorb the shock. These also help in electrical job or painting.

- There are three classes of head protecting equipment:

  Class A – General service, limited voltage protection.

  Class B – Utility service, high voltage helmet.

  Class C – Special service, no voltage.

- **Class A** is intended for protection against head injury.
- **Class B** protects from impact and penetration by falling or flying objects and from high voltage. The materials used for the helmet must be water resistant.
- In case of **Class C**, the helmet is made of aluminum or other light and strong metals and should not be used where there are chances of electricity, static charge, and microwave induction. These should be provided with an air gap between head and the helmet by headbands.

- For eye and face protection, a suitable protection must be worn when there is a reasonable probability of preventing injury when such equipment are used. This is also true for visitors and administrative staff if they are in the hazardous areas.

- The eye and face protective equipment includes safety glasses, chemical goggles, face shields, welding goggles and welding face shields.

- Protectors must be worn in the areas where there is a potential for injury to the eyes or face from flying particles, liquid chemicals, molten metals, acids or caustic vapors or potentially injurious light radiation.

- These PPE should be comfortable, fit snugly without interfering with vision and movement, durable, and cleanable. They should protect from dust, splash, chipper, welder and cutter particles.

- The equipment for noise protection is specific for a specific kind of noise. They may be earplug, made up of rubber, plastic, foam, wool or earmuffs.

- These plugs are disposable as well as non-disposable and can be reused if working properly.

- The primary control to protect employee from dust, mist, fumes, gases and toxic vapors is the engineering control, such as enclosure or confinement of the operation, general and local ventilation and substitution of less toxic materials.

- In addition, appropriate respirators should be provided to protect from occupational diseases.

- Medical examination of the employees should be done before posting him to a contaminated area.

- Employee fit-testing should be carried out for respirator usage. The respirators must be used for its intended purpose, such as for toxic gases, dust particles or mist of chemicals.

- These respirators should be thoroughly cleaned, disinfected and should be kept in a clean and sanitary location after every use.

- The employee should be instructed and trained in using this equipment. This equipment should routinely be inspected and disinfected.

- The employee, who is physically able to perform the work in a hazardous environment, should be assigned tasks requiring use of respirators.

- Active surveillance of working area conditions and degree of employee exposure or stress shall be maintained.

- Protective clothing like vests, jackets, aprons, coveralls, and full body suits should be made available. The employee working near the heat should be given a heat-resistant coat made of leather.

- Rubber and rubberized fabrics, neoprene and plastics give protection against acids and chemicals.

- There is a wide range of gloves available. It is important to know the characteristics of the gloves relative to the specified hazard.

- To protect feet and legs from falling or rolling objects, sharp objects, molten metal, hot surfaces and wet slippery surfaces, a worker should be provided with appropriate foot guard, safety shoes, boots and leggings which protects them from molten metals or welding sparks and the hazards.

2.7.3 Appraising Plant Safety and Practices

- Facts and statistics should be collected from the same kind of facilities regarding frequencies and cause of hazards and incidents.

- Safety engineers are in charge in order to design more accident free plants.

- The job of a safety engineer is to minimize accidents to zero level. High safety-quality plants can achieve these accident free periods by eliminating or minimizing the existence of unsafe conditions before accidents could occur.

- The corrective measure should not be taken after an accident has taken place.

- Safety appraisal is a means to design and construct an accident free facility by analyzing accident frequencies and severity and by taking preventive measures to remove the flaw in the design.

- The job of a safety engineer is to review old or existing plant design, future and old equipment, procedures and operation, the estimates, the chances of hazards and their correction to avoid accidents in a new plant design.

- This appraisal can be done by the following procedures:
  - Any plant should include the proper marking of entrances and exists according to the local codes and must be properly maintained.
  - The electrification and their location must comply with the provisions of a standard code. They should be properly marked as hazardous areas.
  - Firefighting equipment should be installed and maintained by regular checking at regular intervals.
  - Pressure vessels should be designed and tested before operation according to a standard stated.
  - High-energy pressure vessels should be located at a great distance to prevent possible damage due to their failure (explosion).
  - Adequate workspaces should be provided between different equipment to avoid restricted movement of the employee. There should not be any physical interference, which can cause error or accident.
  - Personnel protective equipment should be provided for a particular job.
  - Ventilation and exhaust, hoods, ducts, blowers, filters and scrubbers should be provided and kept in order, clean and operational in order to remove air particulate or toxic chemicals.
  - Emergency equipment and locations for their emplacements or storage should be provided nearest readily accessible locations.
  - Fire lanes and other routes to locations where other emergencies could occur should be provided, marked and maintained.

- The hazardous processes are isolated so they do not constitute danger to other personnel and their activities. Fuel, chemicals, electric power generations, and boilers should be isolated from other facilities to avoid danger.

2.7.4 Planning for Emergencies

- An accident is unavoidable in any industry no matter how good and flawless a safety program is.

- Minimizing the factors that are responsible for hazards are more important than minimizing the effects of an accident.

- The effects of any accident can be minimized by providing emergency relief (rescue) in the shortest time possible to the victim.

- In any plant each supervisor and worker should know where to call for and how to obtain medical aid rapidly and what to do until it arrives.

- Industrial plants may have their own medical staff, or a physician can be called and ambulances may be available in the nearby hospital for rapid transportation.

- First aid measures can be taken till the arrival of qualified staff.

- Medical assistance and firefighters may be requested as soon as possible, while the injured person should be given first aid and should also be moved from the dangerous point.

- Normally it is not advisable to move any injured person if there is no nearby life threatening hazard. This is to avoid aggravating any injury. If it is desirable to move a person, care should be taken that there should not be any stress or strain imposed on the injured part of the body.

- First aid equipment can be made easily accessible and without any hindrance.

- The workers should be given training by a learned paramedical staff for first aid and other similar important practices.

- A good and efficient emergency safety plan should represent a good coordination between administration, engineers, supervisors and workers and security staff.

- The entire program for planning for an emergency control must be a coordinated effort.

- The use of procedures, facilities and personnel, which would be needed in an emergency, must be made as a part of the plant design and operation.

- Although emergency planning and control is a combine effort, one person responsible should be designated for safety, security, firefighting and medical service at the time of the emergency.

- Every worker should be familiar to call an immediate emergency supervisor when necessary.

- The main elements of a ***site emergency response plan (SERP)*** are as follow:
  - A list of emergency phone numbers for company team members, immediate staff personnel, management officials, medical and healthcare officials, rescue services, firefighters,…
  - Site evacuation routes and other alternative routes should be made available for reaching any site of emergency from inside and outside.
  - The location, type and availability of equipment should be available on site from local resources or elsewhere.

- The equipment should meet specific types of emergencies and to bring situations under control. These may include firefighting equipment, emergency medical, communication equipment, and self-contained breathing apparatus.

- Means of communication must be established in order to alert the emergency organization personnel that their services are required.

- Installation of secondary communication systems for emergency use is also required in case of any failure of primary communication sources. Alarm system should be provided for emergency.

- Material safety data sheets (MSDS) on all hazardous materials should be posted at or near the location.

- Every personnel and local response agencies should be familiarized with the hazards of the materials used on site.

- The coordination network must ensure that all involved persons have reviewed the plan, provided their input, understand specific functions and agree to those responsibilities.

- The employees must be given a proper training for emergencies e.g., power disconnect, use of fire extinguishers, use of first aid, as well as search and rescue or emergency response procedures.

- Managers and supervisors must be trained as team coordinators and on site commanders and can effectively serve as liaisons to corporate, regulatory and local agencies.

- Specific capabilities of individual team members must be kept in view and job of emergency response activities may be assigned accordingly.

- The drill, test of various program elements and response capabilities, should be carried out regularly to evaluate response procedures and corrective actions.

- Alarm tests, simulated drills and mock exercises with community groups are several testing approaches. Evaluation results and proposed corrective actions must be documented and incorporated into the plan.

- Involvement of other agencies in the testing drill enhances relations and efficiency of the plan.

- Records maintaining of the past and present drills would help in improving the ESPR.

- An emergency preparedness drill to deal with sabotage and terrorism must also be carried out.