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HYDROCARBON SECTOR
SKILL COUNCIL

Participant Handbook

Sector
Hydrocarbon

Sub-Sector
Midstream

Occupation
Pipeline Maintenance

Reference ID: **HYC/Q6402, VH.0,**
NSQF Level 4

Pipeline Maintenance Technician (Mechanical)

This book is sponsored by

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HYDROCARBON SECTOR SKILL COUNCIL

for

SKILLING CONTENT : PARTICIPANT HANDBOOK

Complying to National Occupational Standards of
Job Role/ Qualification Pack: **Pipeline Maintenance (Mechanical)** QP No. **HYC/Q6402 NSQF Level 4**

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The preparation of this manual would not have been possible without the Hydrocarbon Industry's support. Industry feedback has been extremely encouraging from inception to conclusion and it is with their input that we have tried to bridge the skill gaps existing today in the industry.

This participant manual is dedicated to the aspiring youth who desire to achieve special skills which will be a lifelong asset for their future endeavours.

About this book

Welcome to the **"Pipeline Maintenance Technician (Mechanical)"** training programme. This Participant Hand Book (PHB) will facilitate and train the trainees/participants in the skills necessary to be a **"Pipeline Maintenance Technician (Mechanical)"**, in the Hydrocarbon Sector.

"Pipeline Maintenance Technician (Mechanical)" is someone who is competent to perform the job of installation, troubleshooting, repair, preventive maintenance of pipeline in oil and gas sector while following standard safety procedures. Accordingly, the Participant Handbook (PHB) includes technical as well as behavioural skills required for this job role, and is based on National Skill Qualifications Framework (NSQF) aligned qualification pack and covers the following national occupational standards.

1. Prepare for repair and maintenance of the pipeline equipment (HYC/N6402)
2. Carry out repair, maintenance and testing of equipment in oil and gas pipeline (HYC/N6403)
3. Working effectively in a team (HYC/N9301)
4. Maintain health, safety and security procedures (HYC/N9302)

There are various practical and theoretical exercises given at the end of each unit, which may be used to test the understanding of the trainee on a topic. Participants can use them for formative and summative assessment. This book is just a beginning, and much of the most exciting learning processes will take place in the classroom and thereafter.

Successful completion of the programme shall certify the trainee as a Pipeline Maintenance Technician (Mechanical), thereby adding value for their employment opportunities as also the entrepreneurship capabilities.

Symbols Used

Key Learning Outcomes | Steps | Exercise | Tips | Notes | Unit Objectives | Summary

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It is recommended that all trainings include the appropriate Employability Skills Module Content for the same is available here:

https://www.skillindiadigital.gov.in/content/list

1. Introduction

Unit 1.1 - Introduction to hydrocarbon sector

Unit 1.2 - Roles and responsibilities of a pipeline maintenance technician

Key Learning Outcomes

At the end of this module, the participant will be able to:

1. Describe oil and gas sector and its sub-sectors.
2. List the three major segments in the hydrocarbon sector.
3. State the functions of upstream, midstream and downstream segments.
4. List the roles and responsibilities of a **"Pipeline Maintenance Technician"**

Unit 1.1 - Introduction to hydrocarbon sector

Unit Objectives

At the end of this unit, the participant will be able to:

1. Identify about the hydrocarbon sector in India.
2. Define the market size of hydrocarbon sector.
3. List the three major segments in the hydrocarbon sector.
4. Identify about the investments in hydrocarbon sector.
5. Illustrate the initiatives taken by the government for hydrocarbon sector.
6. Identify about the achievements of hydrocarbon sector.

1.1.1 Hydrocarbon Sector in India – Overview

The oil and natural gas sector is amongst the 8 core industries driving economic growth in India and plays a crucial role in country's economic growth. The industry is broadly divided into following different segments which refers to different points in the process of exploring and extracting, collecting and processing and ultimately distributing the oil and natural gas for use.

The government has adopted several policies to fulfil the increasing demand. It has allowed 100% foreign direct investment (FDI) in many segments of the sector, including natural gas, petroleum products and refineries among others. Today, it attracts both domestic and foreign investment as attested by the presence of Reliance Industries Ltd (RIL) and Cairn India.

India has been the fourth-largest Liquefied Natural Gas (LNG) importer since 2011 after Japan, south Korea, and china.

Market size

India is expected to be one of the largest contributors to NON-OECD petroleum consumption growth globally. Crude oil import rose sharply to US $ 101.4 Billion in 2019-20 from US $ 70.72 Billion in 2016-17. India retained its spot as the third largest consumer of oil in the world in 2019 with consumption of 5.16 Million barrels per day (MBPD) of oil in 2019 compared to 4.56 MBPD in 2016.

As of October 01, 2020, India's oil refining capacity stood at 249.9 Million metric tonnes (MMT), making it the second-largest refiner in Asia. Private companies own about 35.29% Of the total refining capacity in FY 20.

In FY 20, crude oil production in India stood at 30.5 MMT. In FY 20, crude oil import increased to 4.54 MBPD from 4.53 MBPD in fy19. Natural gas consumption is forecast to reach 143.08 Million tonnes (MT) by 2040. India's LNG import stood at 33.68 BCM during FY 20.

India's consumption of petroleum products grew 4.5% To 213.69 MMT during FY 20 from 213.22 MMT in FY 19. The total value of petroleum products exported from the country increased to US $ 35.8 Billion in

FY 20 from US $ 34.9 Billion in fy19. Export of petroleum products from India increased from 60.54 MMT in FY 16 to 65.7 MMT in FY 20.

Gas pipeline infrastructure in the country stood at 17,016 Kms as of June 30, 2020.

1.1.2 Major segments in the hydrocarbon sector

The industry is broadly divided into following different segments which refers to various points in the process of exploring and extracting, collecting and processing and ultimately distributing the oil and natural gas for use.

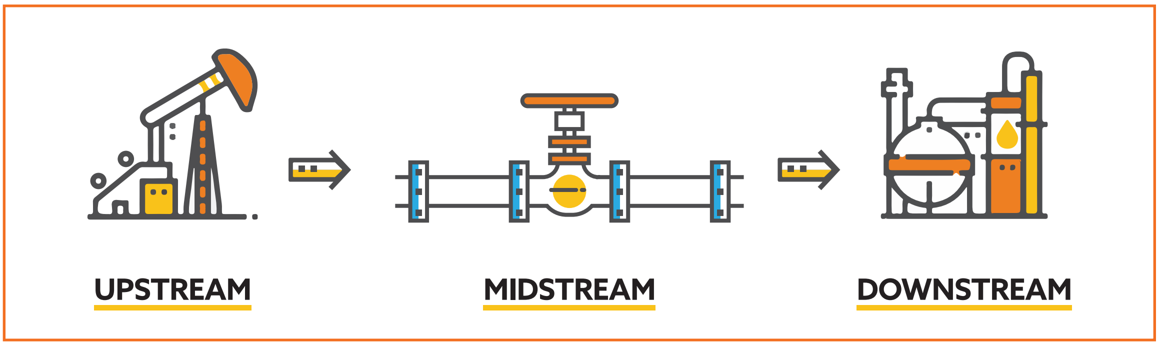

Fig: 1.1.1 Hydrocarbon Segments

The energy sector has three key areas: Upstream, midstream and downstream.

1. **Upstream:** Upstream is E&P (exploration and production). This involves the search for underwater and underground natural gas fields or crude oil fields and the drilling of exploration wells and drilling into established wells to recover oil and gas.

   The term 'upstream' also includes the steps involved in the actual drilling and bringing oil and natural gas resources to the surface, referred to as 'production'.

Fig: 1.1.2 Upstream

2. **Midstream:** Midstream entails the transportation, storage, and processing of oil and gas. Once resources are recovered, it has to be transported to a refinery, which is often in a completely different geographic region compared to the oil and gas reserves. Transportation can include anything from tanker ships to pipelines and trucking fleets.

   Midstream includes pipelines and all the infrastructure needed to move these resources long distances, such as pumping stations, tank trucks, rail tank cars and transcontinental tankers.

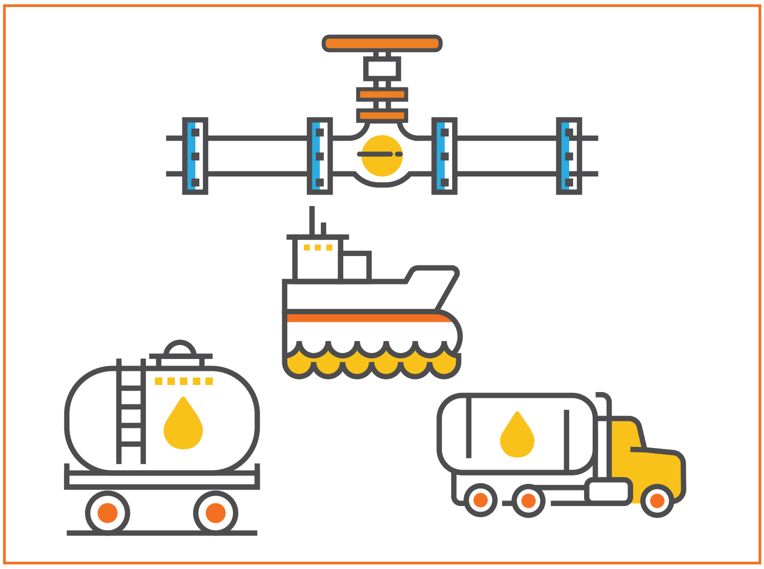

Fig: 1.1.3 midstream

3. **Downstream:** Downstream refers to the filtering of the raw materials obtained during the upstream phase. This means refining crude oil and purifying natural gas. The marketing and commercial distribution of these products to consumers and end users in a number of forms including natural gas, diesel oil, petrol, gasoline, lubricants, kerosene, jet fuel, asphalt, heating oil, LPG (liquefied petroleum gas) as well as a number of other types of petrochemicals.

   Oil and natural gas products are even used to make artificial limbs, hearing aids and flame-retardant clothing to protect fire fighters. In fact, paints, dyes, fibres and just about anything that is manufactured has some connection to oil and natural gas.

   So now you know. 'Upstream' is about extracting oil and natural gas from the ground; 'midstream' is about safely moving them thousands of miles; and 'downstream' is converting these resources into the fuels and finished products we all depend on.

Fig: 1.1.4 Downstream

Together, these three sectors of the oil and natural gas industry sustain the steady flow of fuels and materials that make life better and safer for us all.

1.1.3 Investment

In line with the national skill mission of India, Hydrocarbon Sector Skill Council (HSSC) for the oil & gas sector has been set up under the aegis of Ministry of Petroleum & Natural Gas (MoPNG) with its primary objective to execute skill development activities in Indian hydrocarbon sector and meeting the entire value chain's requirement of appropriately trained manpower in quantity and quality on a sustained and evolving basis.

Key objectives:

- To initiate, carry out, execute, implement, aid and assist activities towards skill development in the Indian hydrocarbon sector and meeting the entire value chain's requirement of appropriately trained manpower in quantity and quality on a sustained and evolving basis.
- Develop a skill development plan for the sector.
- Identify skill development need of the sector, review international trends and identify sector skill gap and technology.
- Develop National Occupational Standard (Nos's) for the job roles of covering the entire sector/ sub-sector.
- Identification and enlistment of training providers as outlined by NSDC.
- Create a pool of skill manpower and creating a benchmark for new skills and upskilling.

1.1.4 Government initiatives

Some of the major initiatives taken by the government of India to promote oil and gas sector are:

- In November 2020, oil regulator petroleum and natural gas regulatory board (PNGRB) simplified the country's gas pipeline tariff structure to make fuel more affordable for distant users and attract investment for building gas infrastructure.
- In November 2020, the Indian government urged OPEC to remove pricing anomalies for different regions with a view to aid the corona-battered global oil industry get back to normalcy.
- As per union budget 2019-20, Indian scheme 'Kayakave Kailasa', the ministry of petroleum & natural gas has enabled SC/ST entrepreneurs in providing bulk LPG transportation. State run energy firms, Bharat Petroleum, Hindustan Petroleum and Indian Oil Corporation, plan to spend US $ 20 billion on refinery expansions to add units by 2022.
- The government is planning to set up around 5,000 compressed biogas (CBG) plants by 2023.
- The government is planning to invest US $ 2.86 Billion in the upstream oil and gas production to double natural gas production to 60 BCM and drill more than 120 exploration wells by 2022.
- Government of India is planning to invest RS. 70,000 Crore (US $ 9.97 Billion) to expand the gas pipeline network across the country.
- In September 2018, Government of India approved fiscal incentives to attract investment and technology to improve recovery from oil fields, which is expected to lead to hydrocarbon production worth RS. 50 Lakh crore (US $ 745.82 Billion) in the next 20 years.

- State-run oil firms are planning investment worth RS. 723 Crore (US $ 111.30 Million) in Utter Pradesh to improve the LPG infrastructure in a bid to promote clean energy and generate employment according to Mr. Dharmendra Pradhan, Minister of Petroleum and Natural Gas, Government of India.
- A gas exchange is planned in order to bring market-driven pricing in the energy market of India and the proposal for the same is ready to be taken to the union cabinet according to Mr. Dharmendra Pradhan, Minister of Petroleum and Natural Gas, Government of India.
- The oil ministry plans to set up BIO-CNG (compressed natural gas) plants and allied infrastructure at a cost of RS. 7,000 Crore (US $ 1.10 Billion) to promote the use of clean fuel.

1.1.5 Achievements

Following are the achievements of the Government during 2019-20:

- LPG penetration rate of households reached ~97% at the beginning of 2020 compared with 56% in 2016.
- The energy trade between India and us is likely to touch US $ 10 billion in FY 20.
- As on march 01, 2020, Gas Authority of India Ltd. (GAIL) had the largest share (71.61% Or 11,411 kms) of the country's natural gas pipeline network (16,324 kms).
- With 8,748 kms of refined products pipeline in India, IOC was leading the segment with 51.25% Of the total length of product pipeline network as on march 01, 2020.
- As on April 01, 2020(p), there were 24,670 LPG distributors (of PSUs) in India.
- The total number of OMC (oil marketing companies) retail outlets increased to 66,817 at the beginning of April 2020(p) from 59,595 at end of FY 17.
- Under city gas distribution (CGD) network, 86 geographical areas constituting 174 districts in 22 states/ union territories are covered.
- OMCs delivered 6.8 Crore LPG cylinders to Pradhan Mantri Garib Kalyan Package (PMGKP) beneficiaries by may 20, 2020.

1.1.6 Road Ahead

Energy demand of India is anticipated to grow faster than energy demand of all major economies on the back of continuous robust economic growth. India's energy demand is expected to double to 1,516 mtoe by 2035 from 753.7 Mtoe in 2017. Moreover, the country's share in global primary energy consumption is projected to increase by two-fold by 2035.

Crude oil consumption is expected to grow at a CAGR of 3.60% To 500 million tonnes by 2040 from 221.56 Million tonnes in 2017.

Natural gas consumption is forecast to increase at a CAGR of 4.18% To 143.08 Million tonnes by 2040 from 58.10 Million tonnes in 2018.

Diesel demand in India is expected to double to 163 million tonnes (MT) by 2029-30.

Notes

Unit 1.2 Roles and responsibilities of a pipeline maintenance technician

Unit Objectives

At the end of this unit, the participant will be able to:

1. Identify roles and responsibilities of pipeline maintenance technician.
2. Identify essential skills of pipeline maintenance technician.
3. Identify career aspects of pipeline maintenance technician.

1.2.1 What does a pipeline maintenance technician do?

Pipeline technician is responsible for the maintenance and correct operation of an oil or gas pipeline system. Troubleshoots, tests, maintains, and repairs pipeline equipment which may include valves, operators, and filtration systems. Being a pipeline technician performs periodic inspections and routine maintenance on the pipeline system. Completes maintenance records, service reports, and other required documents.

Roles and responsibilities of pipeline maintenance technician

A pipeline technician takes responsibility for maintaining and correcting operations at the oil or gas pipeline factory.

Common responsibilities include:

- Completes work orders.
- Schedules maintenance and surveys of pipelines and relevant equipment.
- Performs pipeline rectifier system operations and maintenance.
- Ensures compliance of environmental and governmental regulations.
- Controls and minimizes repair expenses through preventative maintenance plans and procedures.
- Complies with all environmental, health, and safety guidelines.
- Reports any unsafe condition or situation.
- Maintains a clean and safe working environment; may be required to perform some housekeeping activities.
- Makes any or all repairs deemed reasonable and safe.
- May be required to operate a company vehicle, maintaining it to ensure safety.
- Orders equipment as needed.
- Recognizes deviations in operations and takes appropriate action to correct it.
- May be required to read and interpret drawings and schematics.
- Uses hand power tools and other equipment.
- Performs valve and valve operator maintenance tasks.

1.2.2 Pipeline maintenance technician skills

- **Operation monitoring:** Watching gauges, dials, or other indicators to make sure a machine is working properly.
- **Operation and control:** Controlling operations of equipment or systems.
- **Critical thinking:** Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
- **Active listening:** Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.
- **Equipment maintenance:** Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
- **Quality control analysis:** Conducting tests and inspections of products, services, or processes to evaluate quality or performance.
- **Reading comprehension:** Understanding written sentences and paragraphs in work related documents.
- **Monitoring:** Monitoring/assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.
- **Repairing:** Repairing machines or systems using the needed tools.
- **Troubleshooting:** Determining causes of operating errors and deciding what to do about it.
- **Writing:** Communicating effectively in writing as appropriate for the needs of the audience.
- **Speaking:** Talking to others to convey information effectively.
- **Complex problem solving:** Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
- **Judgment and decision making:** Considering the relative costs and benefits of potential actions to choose the most appropriate one.
- **Coordination:** Adjusting actions in relation to others' actions.
- **Time management:** Managing one's own time and the time of others.
- **Social perceptiveness:** Being aware of others' reactions and understanding why they react as they do.
- **Systems analysis:** Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.
- **Instructing:** Teaching others how to do something.
- **Active learning:** Understanding the implications of new information for both current and future problem-solving and decision-making.

1.2.3 Knowledge

- **Customer and personal service:** Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.
- **Production and processing:** Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.
- **Mechanical:** Knowledge of machines and tools, including their designs, uses, repair, and maintenance.
- **English language:** Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.
- **Public safety and security:** Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.

1.2.4 Working conditions

- Field and office environment with regularly scheduled travel and overnight stays.
- Frequent travel to construction sites.
- Frequent over time and flexibility required to manage multiple projects, emergency response operations, adverse weather conditions, work priorities, fieldwork schedules, and out of town travel.
- Shifting priorities to meet changing directions.
- Works independently with little day to day direction.
- Time commitments often extend beyond normal working hours.

Summary

- As defined by WHO, health is a “state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity’’.
- Safety is the state of being ‘safe’, the condition of being protected from harm or other non-desirable outcomes.
- Workers in oil and gas industry are generally susceptible to certain safety and injury hazards such as, motor vehicle accident, contact injuries, fire and explosions, slip, trips and falls etc.
- Workers in oil and gas industry are generally susceptible to chemical hazards, physical hazards, biological hazards, ergonomic hazards, psychosocial hazards.
- It is important that driver, drive shaft,are secured from inadvertent movement before anyone works on the pump.

- It is important to ensure that the steam-and the associated steam condensate system-are properly isolated.
- A systematized approach PDCA should be used for managing occupational safety and health hazards.
- Risk management includes, identifying the risks, evaluating and prioritizing the risks, implementing preventive/protective measures to control the risk.
- Job safety analysis is a process of systematically evaluating certain jobs, tasks, processes or procedures and eliminating or reducing the risks or hazards in order to protect workers from injury or illness.
- Personal protective equipment (PPE) is a clothing or equipment worn by workers to protect them from various hazards.
- Fire extinguishers are designed to tackle specific types of fire.
- There are five different classes of fire, class A, B, C, D, E, K.
- There are different types of fire extinguishers, water extinguisher, dry chemical powder, foam type extinguisher, carbon dioxide extinguisher, special dry powder.
- The fire extinguishers are used by following PASS technique.
- First aid is the first assistance or treatment given to a casualty or a sick person for any injury or sudden illness before the arrival of an ambulance.
- Cardiopulmonary resuscitation (CPR) is a lifesaving technique. It aims to keep blood and oxygen flowing through the body when a person's heart and breathing have stopped.

Exercise

1. **India's oil refining capacity was 249.9 million metric tons (MMT) as of October 1, 2020, making it the second largest refiner in Asia.** (True/False)
2. **In 2011, India became the fourth largest importer of Liquefied Natural Gas (LNG), after Japan, South Korea, and China.** (True/False)
3. **Production is another term used to describe the actual drilling and bringing of oil and natural gas to the surface, occasionally referred to as "upstream".**

   ....

   ....

   ....

   ....
4. **Oil and natural gas products are even used to make artificial limbs, hearing aids and flame-retardant clothing to protect fire-fighters.**

   a) Oil and natural gas

b) Crude oil and natural gas

c) LPG and natural gas

d) Kerosene and heating oil

5. **The full of OISD is**

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Scan the QR codes or click on the link to watch the related videos

https://youtu.be/W-PooTpdcyw

The People Behind The Pipeline

Notes

Notes

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2. Prepare for repair and maintenance activities of the equipment

Unit 2.1 - Introduction to crude oil

Unit 2.2 - Equipment and machines

HYC/N6402

Key Learning Outcomes

At the end of this module, the participant will be able to:

1. Identify the oil and gas pipeline equipment that are meeting its safety and technical standards.
2. Examine the identified defect/damage in equipment/machine.
3. Follow the maintenance manual of the machine and equipment requiring maintenance or repair..

Unit 2.1 - Introduction to crude oil

Unit Objectives

At the end of this unit, the participant will be able to:

1. Identify the origin and processes of crude oil.
2. Identify the natural gas processes.
3. Describe the pipelines and its various types.

2.1.1 What is Crude Oil?

Crude oil is a naturally occurring, unrefined petroleum product composed of hydrocarbon deposits and other organic materials. A type of fossil fuel, crude oil can be refined to produce usable products such as gasoline, diesel, and various other forms of petrochemicals. It is a non-renewable resource, which means that it can't be replaced naturally at the rate we consume it and is, therefore, a limited resource.

Where does crude oil come from?

Crude oil is formed from the remains of dead organisms (diatoms) such as algae and zoo plankton that existed millions of years ago in a marine environment.

These organisms were the dominant forms of life on earth at the time.

As they lived these organisms absorbed energy from the sun and stored it as carbon molecules within their bodies. Once they died their remains sank to the bottom of the oceans or riverbeds and were buried in layers of sand, mud and rock.

Over millions of years, the remains were buried deeper and deeper under more sediment and organic materials.

The enormous pressure, high temperatures, and lack of oxygen transformed the organic matter into a waxy substance called kerogen.

With even more heat, pressure, and time the kerogen undergoes a process called catagenesis which transforms the kerogen into hydrocarbons.

Different combinations of pressure, heat, and the original composition of organic material will determine the type of hydrocarbon formed. In this case, the hydrocarbons form crude oil.

Other examples are asphalt if the temperature is lower, and natural gas if the temperature is higher.

After the oil is formed it moves through tiny pores in the surrounding rock from an area of high pressure to low pressure, this is often upwards.

Some oil might make it all the way to the surface where it pools, in other cases the oil will get trapped under impermeable layers of rock or clay where it will form underground reservoirs.

The process of crude oil refining

Once crude oil is extracted from the ground, it must be transported and refined into petroleum products that have any value. Those products must then be transported to end-use consumers or retailers (like gasoline stations or the company that delivers heating oil to your house, if you have an oil furnace). The overall well-to-consumer supply chain for petroleum products is often described as being segmented into three components.

- Upstream activities involve exploring for crude oil deposits and the production of crude oil. Examples of firms that would belong in the upstream segment of the industry include companies that own rights to drill for oil (e.g., Exxonmobil) and companies that provide support services to the drilling segment of the industry (e.g. Halliburton).
- Midstream activities involve the distribution of crude oil to refiners; the refining of crude oil into saleable products; and the distribution of products to wholesalers and retailers. Examples of firms that would belong in the midstream segment of the industry include companies that transport oil by pipeline, truck or barge (e.g., Magellan pipeline); and companies that refine crude oil (e.g., Tesoro).
- Downstream activities involve the retail sale of petroleum products. Gasoline stations are perhaps the most visible downstream companies, but companies that deliver heating oil or propane would also fall into this category.

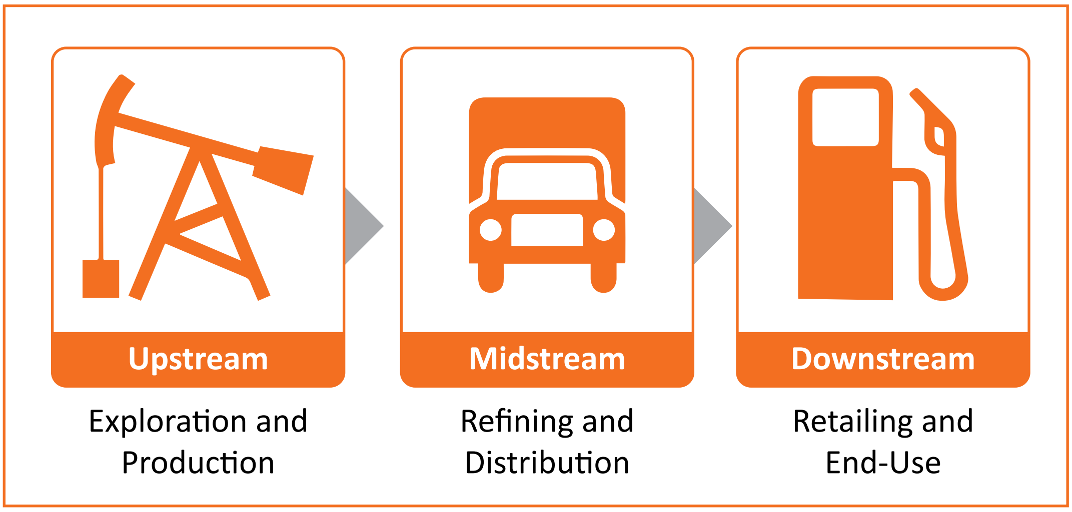


Fig: 2.1.1 Well-to-consumer supply chain for petroleum products. Upstream Midstream and Downstream

Petroleum refineries are large-scale industrial complexes that produce saleable petroleum products from crude oil (and sometimes other feed stocks like biomass). The details of refinery operations differ from location to location, but virtually all refineries share two basic processes for separating crude oil into the various product components. Actual refinery operations are very complicated, but the basic functions of the refinery can be broken down into three categories of chemical processes.

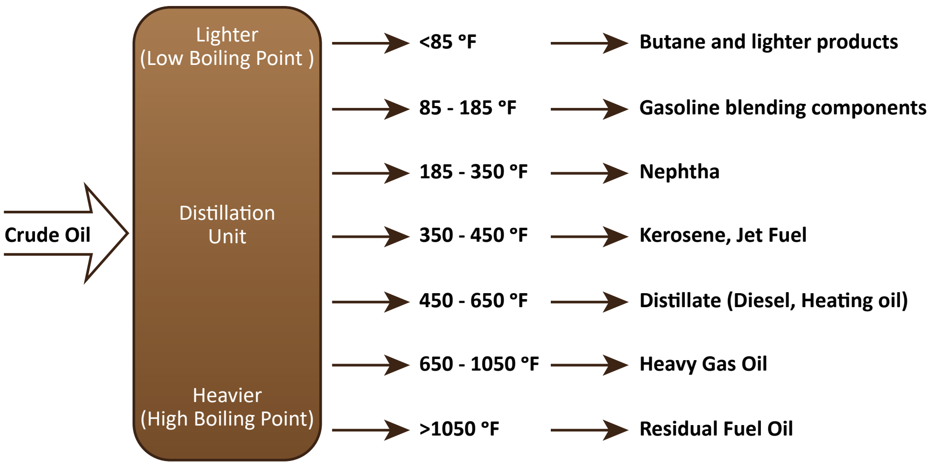
- Distillation involves the separation of materials based on differences in their volatility. This is the first and most basic step in the refining process, and is the precursor to cracking and reforming.
- Cracking involves breaking up heavy molecules into lighter (and more valuable) hydrocarbons.
- Reforming involves changing the chemical nature of hydrocarbons to achieve desired physical

properties (and also to increase the market value of those chemicals).

The first process is known as distillation. In this process, crude oil is heated and fed into a distillation column. A schematic of the distillation column is shown in below given figure.

As the temperature of the crude oil in the distillation column rises, the crude oil separates itself into different components, called **"fractions."** The fractions are then captured separately. Each fraction corresponds to a different type of petroleum product, depending on the temperature at which that fraction boils off the crude oil mixture.

Crude oil distillation unit and products



This simplifies drawing shows many of a refinery's most important process

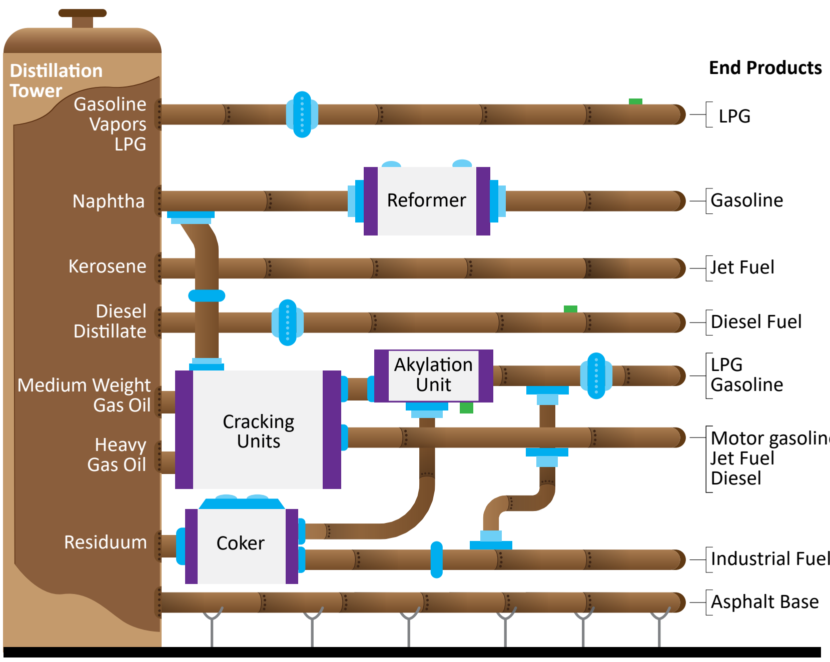


Fig: 2.1.2 Important processes of a refinery

The second and third processes are known as cracking and reforming. The figure shown above provides a simplified view of how these processes are used on the various fractions produced through distillation. The heaviest fractions, including the gas oils and residual oils, are lower in value than some of the lighter fractions, so refiners go through a process called **"cracking"** to break apart the molecules in these fractions. This process can produce some higher-value products from heavier fractions. Cracking is most often utilized to produce gasoline and jet fuel from heavy gas oils. Reforming is typically utilized on lower-value light fractions, again to produce more gasoline. The reforming process involves inducing chemical reactions under pressure to change the composition of the hydrocarbon chain.

2.1.2. Natural gas processing

Natural gas transported on the mainline natural gas transportation (pipeline) system must meet specific quality measures so that the pipeline network (or grid) can provide uniform quality natural gas. Wellhead natural gas may contain contaminants and hydrocarbon gas liquids (HGL) that must be removed before the natural gas can be safely delivered to the high-pressure, long-distance pipelines that transport natural gas to consumers. Natural gas typically moves from natural gas and oil wells through a gathering system of pipelines to natural gas processing plants for treatment.

Natural gas processing can be complex and usually involves several processes, or stages, to remove oil, water, HGL, and other impurities such as sulphur, helium, nitrogen, hydrogen sulphide, and carbon dioxide. The composition of the wellhead natural gas determines the number of stages and the processes required to produce pipeline-quality dry natural gas. These stages and processes may be integrated into one unit or operation, be performed in a different order or at alternative locations (lease/plant), or not be required at all.

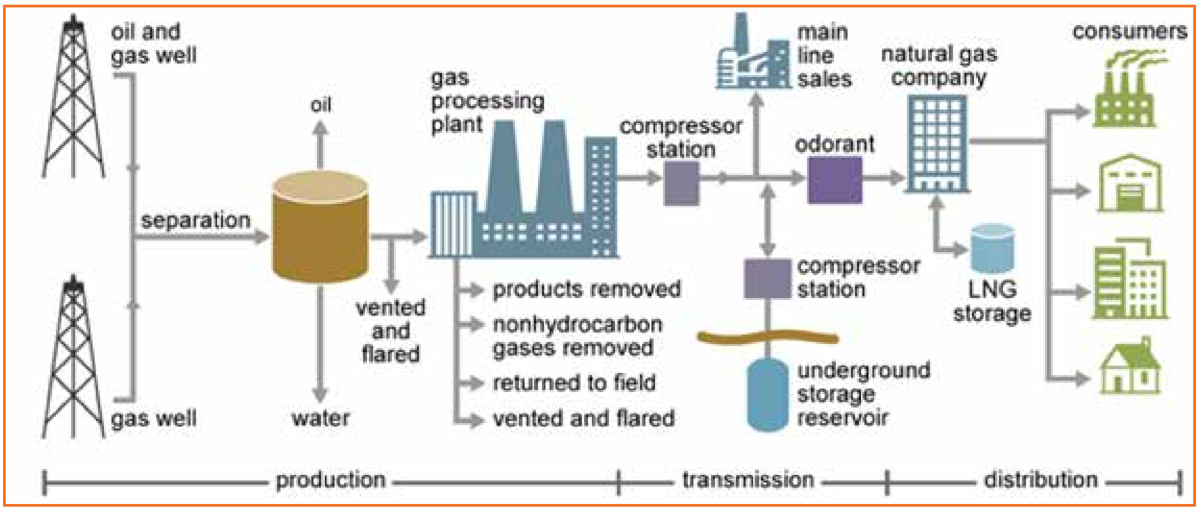


Fig: 2.1.3 Typical Gas Plant

The basic stages of natural gas processing/treatment are:

- **Gas-oil-water separators:** pressure relief in a single-stage separator causes a natural separation of the liquids from the gases in the natural gas. In some cases, a multi-stage separation process is required to separate the different fluid streams.

- **Condensate separator:** Condensates are most often removed from the natural gas stream at the wellhead with separators much like gas-oil-water separators. The natural gas flow into the separator comes directly from the wellhead. Extracted condensate is sent to storage tanks.
- **Dehydration:** A dehydration process removes water that may cause the formation of undesirable hydrates and water condensation in pipelines.
- **Contaminant removal:** Non-hydrocarbon gases - such as hydrogen sulphide, carbon dioxide, water vapour, helium, nitrogen, and oxygen - must also be removed from the natural gas stream. The most common removal technique is to direct the natural gas though a vessel containing an amine solution. Amines absorb hydrogen sulphide and carbon dioxide from natural gas and can be recycled and regenerated for repeated use.
- **Nitrogen extraction:** Once the hydrogen sulphide and carbon dioxide are reduced to acceptable levels, the natural gas stream is routed to a nitrogen rejection unit (NRU), where it is further dehydrated using molecular sieve beds.
- **Methane separation:** The process of demethaniser the natural gas stream can occur as a separate operation in a natural gas processing plant or as part of the NRU operation. Cryogenic processing and absorption methods are some of the ways used to separate methane from HGL.
- **Fractionation:** fractionation separates the HGL into component liquids using the varying boiling points of the individual HGL. HGL from the processing plant may be sent to petrochemical plants, oil refineries, and other HGL consumers.

Natural gas transport

Once natural gas is extracted, it must be transported to different places to be processed, stored, and then finally delivered to the end consumer.

Natural gas can be transported on land via pipeline or on water via ship.

Most of the world's natural gas is delivered by pipeline. Large networks of pipelines quickly deliver natural gas on land to major processing facilities and end consumers. This complex network includes three types of pipelines along the transportation route.

1. **Gathering pipeline system:** The gathering system includes low pressure small pipelines that transport raw natural gas from the wellhead to the processing plant.
2. **Intrastate/interstate pipeline system:** Pipelines can be classified as intrastate or interstate. Their technical and operational characteristics are substantially similar, and they both have the same goal - to transport natural gas from the processing plant to the centres of its consumption.
3. **Distribution pipeline system:** The distribution pipeline system has the purpose of delivering gas to the end-consumers.

Natural gas must be highly pressurized to move it along the pipeline. To ensure that the natural gas remains pressurized, compressor stations are placed in intervals along the pipeline. The natural gas enters the compressor station, where it is compressed by either a turbine, motor, or engine. Metering stations are also installed throughout the pipeline network to monitor for pressure, flow and leaks.

Where natural gas cannot be delivered on land, it can be liquefied and delivered by ship. Compared to gas pipelines, liquefied natural gas (LNG) shipping is preferred for international transport because, in a liquid form, natural gas takes up less volume, making it easier for shipment and storage. LNG infrastructure includes a gas pipeline leading to the seaside, gas liquefaction plant, storage facilities and an LNG terminal for shipment. After being liquefied and transported to the area of demand, LNG is returned to gas form at re gasification plants at the terminal.

Natural gas can also be stored for later use.

What is natural gas storage?

Natural gas is stored during periods of lower demand and withdrawn during periods of higher demand. Natural gas storage is most often used to meet seasonal demand.

Natural gas is stored underground and under pressure in three types of facilities.

- **Depleted natural gas or oil field:** The most common storage method is in depleted natural gas or oil fields, typically close to consumption centres. By converting a field into a storage facility, companies can take advantage of existing wells, gathering systems, and pipeline connections. They are the most common sites because of their wide availability.
- **Aquifer reservoir:** An aquifer is suitable for gas storage if the water-bearing sedimentary rock formation is overlaid with an impermeable cap rock. While the geology of aquifers is similar to depleted production fields, their use in gas storage usually requires more base (cushion) gas and greater monitoring of withdrawal and injection performance. Deliver ability rates may be enhanced by the presence of an active water drive.
- **Salt caverns:** These storage facilities provide very high withdrawal and injection rates relative to their working gas capacity. Base gas requirements are relatively low. The large majority of salt cavern storage facilities have been developed in salt dome formations located in the gulf coast states. Cavern construction is more costly than depleted field conversions when measured on the basis of dollars per thousand cubic feet of working gas capacity, but the ability to perform several withdrawal and injection cycles each year reduces the per-unit cost of each thousand cubic feet of gas injected and withdrawn.

Liquefied natural gas (LNG) is stored above grounds in storage tanks that are specially designed to maintain the low temperatures required to keep the gas in liquid form.

2.1.3 Pipelines

It is generally the case that all crude oils, natural gas, liquefied natural gas, liquefied petroleum gas (LPG) and petroleum products flow through pipelines at some time in their migration from the well to a refinery or gas plant, then to a terminal and eventually to the consumer. Aboveground, underwater and underground pipelines, varying in size from several centimetres to a metre or more in diameter, move vast amounts of crude oil, natural gas, LHGs and liquid petroleum products. Pipelines run throughout the world, from the frozen tundra of Alaska and Siberia to the hot deserts of the middle east, across rivers, lakes, seas, swamps and forests, over and through mountains and under cities and towns. Although the initial construction of pipelines is difficult and expensive, once they are built, properly maintained and operated, they provide one of the safest and most economical means of transporting these products.

The first successful crude-oil pipeline, a 5-cm-diameter wrought iron pipe 9 km long with a capacity of about 800 barrels a day, was opened in Pennsylvania (US) in 1865. Today, crude oil, compressed natural gas and liquid petroleum products are moved long distances through pipelines at speeds from 5.5 To 9 km per hour by large pumps or compressors located along the route of the pipeline at intervals ranging from 90 km to over 270 km. The distance between pumping or compressor stations is determined by the pump capacity, viscosity of the product, size of the pipeline and the type of terrain crossed. Regardless of these factors, pipeline pumping pressures and flow rates are controlled throughout the system to maintain a constant movement of product within the pipeline.

Types of pipelines

The four basic types of pipelines in the oil and gas industry are flow lines, gathering lines, crude trunk pipelines and petroleum product trunk pipelines.

- **Flow lines:** Flow lines move crude oil or natural gas from producing wells to producing field storage tanks and reservoirs. Flow lines may vary in size from 5 cm in diameter in older, lower-pressure fields with only a few wells, to much larger lines in multi-well, high-pressure fields. Offshore platforms use flow lines to move crude and gas from wells to the platform storage and loading facility. A lease line is a type of flow line which carries all of the oil produced on a single lease to a storage tank.
- **Gathering and feeder lines:** Gathering lines collect oil and gas from several locations for delivery to central accumulating points, such as from field crude oil tanks and gas plants to marine docks. Feeder lines collect oil and gas from several locations for delivery direct into trunk lines, such as moving crude oil from offshore platforms to onshore crude trunk pipelines. Gathering lines and feeder lines are typically larger in diameter than flow lines.
- **Crude trunk pipelines:** Natural gas and crude oil are moved long distances from producing areas or marine docks to refineries and from refineries to storage and distribution facilities by 1 to 3 m - or larger diameter trunk pipelines.
- **Petroleum product trunk pipelines:** These pipelines move liquid petroleum products such as gasoline and fuel oil from refineries to terminals, and from marine and pipeline terminals to distribution terminals. Product pipelines may also distribute products from terminals to bulk plants and consumer storage facilities, and occasionally from refineries direct to consumers. Product pipelines are used to move LPG from refineries to distributor storage facilities or large industrial users.

Exercise

1. **.. formed from the remains of dead organisms that existed millions of years ago in a marine environment.**
   a) Natural Gas b) Crude Oil
   c) Gasoline d) Hydrocarbon
2. **.. activities involve exploring for crude oil deposits and the production of crude oil.**
   a) Lowstream b) Upstream
   c) Downstream d) Midstream
3. **Which one of the following is not a type of pipeline system in oil and gas industry?**
   a) Flow lines b) Gathering and feeder lines
   c) Crude trunk pipelines d) Gathering product pipelines
4. **These types of lines collect oil and gas from several locations for delivery to central accumulating points, such as from field crude oil tanks and gas plants to marine docks.**
   a) Flow lines b) Gathering and feeder lines
   c) Crude trunk pipelines d) Gathering product pipelines

Notes

Unit 2.2 - Equipment and machines

Unit Objectives

At the end of this unit, the participant will be able to:

1. Identify what work permit is and how to obtain the work permit from concerned department/ authority.
2. Identify the different types of equipments and machines used and are meeting its safety and technical standards.
3. Examine the identified defect/damage in equipment/machine.

2.2.1 Work Permit System

A permit to work (PTW) system is a document which sets out the work to be done, precautions to be taken for all foreseeable hazards involved & records the state of equipment when handed over while it does not itself make the job safe. It makes the work method fool-proof.

Examples of jobs needing work permits are those requiring employees to enter and work in confined spaces, to repair, maintain or inspect electrical installations or to use large or complex equipment.

Role and purpose of a permit - to- work system

When a job has the potential of causing serious injuries or death, it is necessary to formalize agreed upon work procedures. This prevents instructions from being missed, forgotten or misinterpreted. It also serves as a checklist to ensure that all hazards have been identified and evaluated. Work permit is issued for non-routine work and not for routine work like cleaning, housekeeping etc.

In addition, the occupier or supervisor and the assigned worker(s) will be able to verify that all requirements and conditions are complied with and before the job is started.

Types of permit

Permit- to- work (PTW) covers many different types of operations and tasks, and the following are examples of types of job where permits should be considered.

- Work where heat is used or is generated, for example welding, grinding, etc.
- Work which involves breaking containment of a flammable or dangerous substance.
- Work which involves breaking containment of a pressure system.
- Work on electrical equipment.
- Work within tanks and other confined spaces.
- Working at height.
- Work involving hazardous substances.
- Well intervention.
- Diving operations.

- Work involving pressure testing.

1. **Hot work permit**

   This is issued for work which involves the application of heat or sources of ignition to vessels or equipment which may contain or have contained flammable vapour. Also for areas in which there may be a flammable atmosphere. Hot work permits are typically coloured red or are red- edged.

2. **Cold work permit**

   This is issued for work involving hazardous activities which are not covered by a hot work permit.

3. **Electrical work permit**

   As it suggests, this permit is used when working on a piece of equipment or a circuit that is safe. A permit should never be issued for work on live equipment.

4. **Confined spaces entry certificate**

   These certificates are used when entry to a confined space is essential for work to be done. They should specify all of the precautions necessary to ensure that exposure to hazardous fumes or an oxygen- depleted atmosphere is eliminated before entry to the confined space is permitted.

Although the certificate should confirm that the enclosed space is free from asphyxiating gases or hazardous fumes, it should also specify any precautions necessary to protect the worker(s) from exposure to the risk of harm from other sources, e.g.

- The ingress of airborne contaminants from other sources.
- Hazardous fumes being released from residues within the confined space.

Oxygen depletion caused by oxidation and these precautions can include:

- Use of forced ventilation.
- Provision of personal protective equipment including breathing apparatus

2.2.2 Pressure vessels

Pressure vessels are leak-proof containers that store liquid or gas. Pressure vessels of various sizes and shapes have been produced for different purposes. Generally, preferred geometries are spherical, conical, and cylindrical. A typical model is the combination of a long cylinder with two heads. Pressure vessels work at internal pressures higher or lower than air pressure. Besides, the operating temperatures of these systems differentiate.

How does it work?

Pressure vessels are designed to work by reaching the level of pressure required to make an application function, like holding air in a scuba tank. They can deliver pressure either directly through valves and release gauges, or indirectly via heat transfer. Potential pressure levels range from 15 PSI up to around 150,000 PSI, while temperatures are often above 400°C (750°F). A pressure tank can hold anywhere from 75 litres (20 gallons) to several thousand litres.

2.2.3 Reflux vessels

Reflux vessels feed cool liquid to columns and vessels. Therefore, during an emergency, the reflux system will generally be kept in operation to ensure that heat continues to be removed. The reflux vessel and its associated pumps and piping should be protected against external fire, either with fireproofing or water sprays.

Small pipe connections

The number of small pipe connections on a vessel should be limited. Threaded gauge connections, sample points, and level control nozzles are all subject to mechanical damage, vibration fatigue, and corrosion. The potential failure points are minimized by:

- Installing only those connections actually needed.
- Making the pipe attachments as short as possible.
- Using extra heavy pipe nipples and 3/4 feet minimum diameter to the first valve off the vessel.
- Using socket-weld fittings, especially between the vessel and the first valve.

2.2.4 Storage tanks

Unlike pressure vessels, storage tanks are not designed to handle either high pressure or vacuum conditions. Typically, the tank is open either to the atmosphere or to a part of the system (such as a flare or vent header) that is guaranteed to be at atmospheric pressure.

Broadly, storage tanks fall into one of two categories: fixed roof and floating roof.

Fixed roof tanks

A fixed roof tank contains liquid with a vapour space above it. When the tank is discharged through the vent. If the vapours are hazardous or detrimental to the environment, they will be discharged to a scrubber system and/or a flare. The vent must be big enough to handle the maximum flow of liquid into the tank.

When the tank is being emptied, gas must be added to the vapour space, otherwise the tank could collapse. If the liquid material is flammable it is normal practice to add nitrogen or some other blanketing gas, such as fuel gas, that does not contain oxygen.

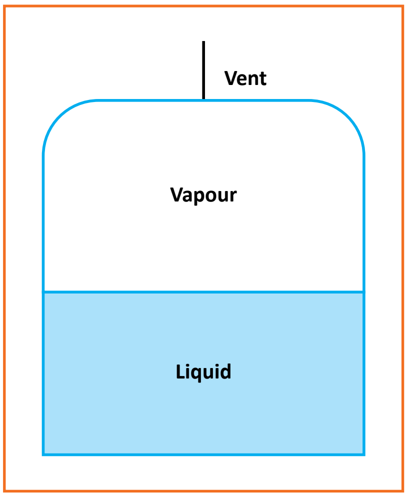


Fig: 2.2.1 Fixed roof tank diagram

Steel tanks over 5 meters in diameter do not generally need ground rods for lightning protection. These tanks are considered adequately grounded because of the contact between the tank bottom and earth. When adding non conductive tank bottoms or liners to the tank for leak protection, ground rods are needed.

The flow of nitrogen into the tank can be continuous or it can be controlled by pressure or the concentration of oxygen in the vapour space. It is generally the most efficient in terms of nitrogen use.

Vapour recovery systems on tanks and vessels can result in vapours in the flammable range being released.

- Vapour lines should be electrically conductive to prevent static build-up.
- Use of mechanical equipment to move vapours should be minimized. If it has to be used then it should be non sparking.
- Atmospheric vents should be located well away from possible ignition sources.
- Unclassified electrical equipment should be at least 20 meters away from vapour recovery equipment.
- In waste handling facilities, activated carbon adsorption units can be overheated to ignition temperatures. These systems should be protected by detonation arresters and high bed temperature shut downs.
- Flares, thermal oxidizer's, and incinerators are open flame devices that may require flame arrestors or other devices to prevent flashback.

Floating roof tanks

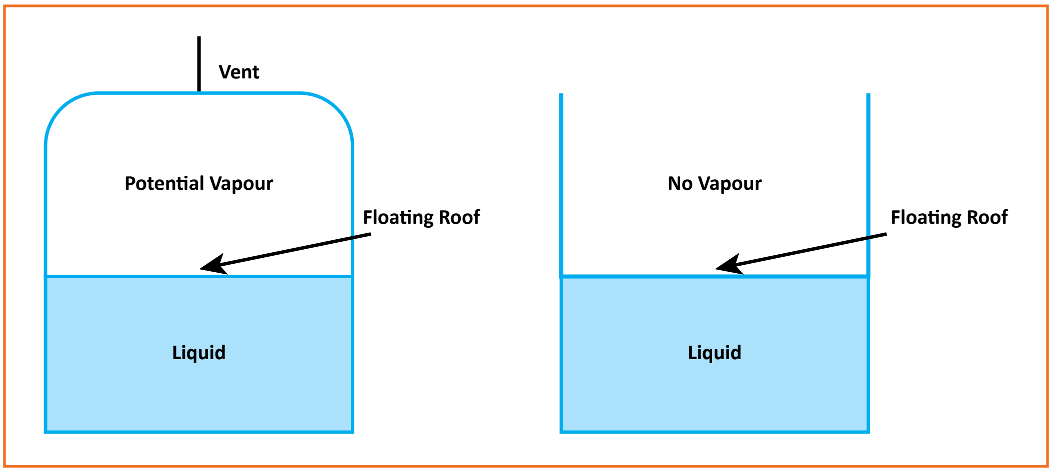


Fig: 2.2.2 Floating roof tank diagram

The basic idea of a floating roof tank is that the roof is in contact with the liquid surface. It is attached to the sides of the tank with rollers. A seal between the moving roof and the tank wall prevents process vapours from leaking into the space above the roof. As liquid is added, the roof moves up; as liquid is removed, the roof moves down. At no time is there a vapour space directly above the liquid.

Hence there is no need to vent the tank when it is being filled and there is no need to add inert gas when it is being emptied.

Many floating roof tanks do not have a fixed roof. Hence, when looking down on a large tank farm from an airplane, it is possible to see the status of the roof positions by looking down on them.

Many tank fires are caused by lightning (either induced charges or direct strikes).

The following actions minimize the chance of a fire:

- The roof seals should be maintained in a good condition.
- Floating roofs should be bonded to the tank walls by the use of shunts spaced at least 3 meters apart. The shunts should be in contact with the wall of the tank.
- The tank roof should be kept clean.
- All openings such as man-ways and inspection hatches should have sealed covers.
- Pontoons need to be inspected at least annually for presence of liquid or flammable vapours.

The potential for contamination of the atmosphere above the internal floating roof is great. Entry onto the roof of an internal floating roof tank constitutes entry into a confined space, so confined space entry procedures must be followed. Provisions for personnel support and distribution of weight must be provided when personnel are on the internal floating roof.

The internal floating roof in a covered tank may be a steel pontoon roof, a steel pan roof, an aluminium floating cover with pontoons or floats, or a fibreglass polyester skin panel deck. Aluminium and polyester roofs have a greater fall through potential than steel roofs. In addition, mechanical damage, corrosion, or other defects may not be readily apparent.

The following guidance applies to work carried out on the roof of a floating roof tank:

- The level of the floating roof should be within about 8 feet of the top of the tank, and no product movement should occur into or out of the tank for 24 hours prior to entry.
- The roof should be essentially horizontal with no evidence of tipping or **"hanging up."**
- The vent should also be a vacuum breaker for use when the tank roof is falling.
- Workers should not enter the floating roof space to determine if liquids are present.
- No entry should be allowed if significant liquid hydrocarbon is present or is suspected to be present on the floating roof.
- Suitable personnel protective equipment should be used.
- Adequate roof support should be assured before anyone walks on the roof.
- Electrical equipment, including lighting, that is used during inspection/work on the internal floating roof should be explosion proof.
- On large-diameter tanks, more than one entry point should be provided to lessen the distance to be covered from the entry point and to minimize the possibility of air and tag (rescue) lines becoming entangled around columns.
- Hot work should not be permitted inside the space of an in-service internal floating roof tank.

2.2.5 Pumps

Pumps are at the heart of all process facilities. They are also a source of hazards because they have moving parts and a seal between their contents and the atmosphere. Hence they are more likely to leak than vessels or piping. If the pump contents are above the liquid's flash point, then a flammable vapour cloud could form.

Pump casing

Pumps will generally have steel or alloy casing. The use of cast iron casing should be limited to non hazardous, non critical service, and such pumps must be installed in such a manner that connecting piping will not excessively stress pump cases.

Although pump casing failures are likely to be extremely serious, they are also quite rare. Causes of casing failure include overpressure, mechanical stress, and reaction with the process materials. If the internal rotating or reciprocating element fails, then there is likely to be a major process upset. However, such a failure will probably not create safety problems because the casing will remain intact. Casing failures are normally very serious because:

- They can lead to a major release of process chemicals.
- The casing sometimes serves as a support for the other equipment.
- As it fails, the casing may send fragments of metal flying through the air - these can injure people and seriously damage other equipment.

Small fittings on pump cases for pressure gages, sample connections, vapour vents, and drains should be seal-welded to the pump case up to the first valve. Where vibrations may be severe, the fitting should be braced.

Seals and packing

Seal failures are the most common type of failure associated with rotating equipment. Since seals are a barrier between the process and the atmosphere, such failures are often likely to lead to environmental problems, and potentially a safety problem depending on factors such as the flammability/toxicity of the process fluid, the size of the leak, and its proximity to personnel or ignition sources. Seal failures can be caused by problems with the bearings, couplings, and shaft vibration.

Mechanical seals, either single or double, are generally preferred over packing because of their higher reliability, longer life, and lower probability of leakage.

Double seals reduce the frequency of seal failures and also reduce the consequences of a leak that may occur.

Where serious hazard might result from leakage, pumps handling hot oils in excess of 175°C should be fitted with water quench glands. Water deluge should be provided over pumps handling liquids above their autoignition temperature or above 315°C. Water sprays should be remotely operated from a point at least 15 meters from the pump being protected.

Minimum flow bypass

A common cause of seal failures of centrifugal pumps is blocking in the pump while it is still running (or starting up the pump with the discharge block valve closed). Although this scenario is not usually hazardous for a short period of time, it can lead to overheating and seal failure. Cooling water pumps, e.g., Have been known to rupture when blocked in while running. The water in the casing is heated to the point where it starts to boil, the seal leaks, but not enough to relieve the rapidly rising pressure, and so the casing ruptures.

When a blocked discharge could be a problem, or when large turn down ratios are anticipated, the installation of a minimum flow bypass should be considered. This type of bypass opens when the flow of liquid leaving the pump falls below a minimum value. The bypass returns discharge liquid to the suction of the pump. Since the liquid is heated as it goes through the pump, it may be necessary to put a cooler on the recycle stream, or to have the recycle stream flow to a suction tank or vessel that contains a large inventory of liquid.

Pump isolation

To prevent escalation of an incident, emergency isolation valves for the suction of pumps should be considered when the pump is fed by a vessel containing 10 cubic meter or more of inventory of materials that are flammable or toxic. In critical services, the valves on either side of the pump should be able to close quickly-usually through an automatic shut down systems. They should also be fireproofed. If manual isolation valves are used, they should be at least 15 meters from the pumps or the likely location of a fire. Emergency isolation valve design options include the following:

- Retrofitting an existing pump suction valve with an actuator.
- Installing a quarter turn fire-safe valve with a fail-safe mechanical spring actuator.
- Installing a quarter turn fire-safe ball valve or butterfly valve with an air piston or diaphragm actuator.
- Installing a spring-loaded quick closing valve.
- Installing an air or electric motor-operated valve with fireproofed actuator and controls.

For pairs of pumps, an emergency isolation valve should be installed on the suction of each pump so that the valves can be tested during normal operations.

Thermal pressure relief valves may be needed for low or ambient temperature pumps that can be blocked in and that could be exposed to sunlight or another heat source.

Safety issues

Pumps should be checked for the following potential problems:

- Cracks or holes in the casing.
- Failure of small piping attachments.
- Thread corrosion on plugs and pipe nipples.
- Inadequate thread engagement.
- Seal or packing leaks.
- Poor gasket.

For high-pressure, high-temperature, and high-capacity pumps, the following protective instrumentation should be considered:

- Low suction pressure alarm.
- Vibration monitoring and shut down.
- High bearing temperature alarm.
- High discharge pressure alarm.
- Seal failure (leak) alarm (for double seal pumps)

2.2.6 Compressors

Many of the comments made about pumps can also be made about compressors. They also have moving parts and seals which are liable to failure.

- **Liquid knock out on the compressor suction:** One of the most serious failure modes for a compressor is for liquid to enter the casing. The result of this failure could be a catastrophic failure of the casing and/ or the compressor internals. Liquid knock out pots and scrubbers are ordinarily provided in suction lines for this purpose. High-level alarms and compressor shut down devices should be installed on knock out pots and scrubbers.
- **Relief valves:** Adequate relief valve capacity must be provided for each cylinder or group of cylinders on a positive displacement compressor discharging into a common header. The discharge from these valves must extend outside any compressor enclosure.
- **Compressor isolation:** The general principles to do with isolation valves are similar to those for pumps, as discussed above. In addition, ventilation of the packing area must be designed so that flammable gases do not flow into the crankcase as this would pose a serious explosion risk.

  Air leaks into a compressor, or residual air left after a shut down, may create an explosive hazard. For this reason, it is advisable to provide purging lines to the compressor; they will be used after the compressor has been opened to atmosphere. It is also a good practice to eliminate unnecessary vents on suction lines and to minimize bypass lines and valves connecting discharge and suction lines.

  Ventilation of the packing area must be designed so that flammable gases are not forced into the crankcase. This would pose a serious explosion risk due to the presence of air. Vents should be extended outside and above the eaves of any enclosure.

  Where pulsating discharge from reciprocating compressors results in pipe vibration so serious that piping and equipment may fail, the installation of additional pulsation dampeners may be warranted.
- **Shut down and alarm systems:** Compressors should be provided with shut down stations at expected personnel access points and at a safe distance from the equipment so that, in the event of a hazardous occurrence, the compressors and their drivers can be controlled and shut down without endangering personnel.

Typical alarm and shut down considerations for major compressor/turbine installations include the following:

1. A high-level alarm on a knock out drum immediately ahead of a compressor, a high level switch to shut down the prime mover, and an alarm to indicate that the machine has shut down.
2. A low-pressure local alarm on the lube oil to a turbine or a compressor, a low pressure switch to shut down the prime mover, and an alarm to indicate that the machine has shut down.
3. A low differential pressure or low oil pot level on the seal oil system, a low seal oil differential pressure or low seal oil pot level switch to shut down the prime mover, and an alarm to indicate that the machine has shut down.
4. **Additional shut down systems include the following:**
    - High vibration.
    - Low suction pressure or low flow.
    - High discharge pressure (for reciprocating compressors).
    - High discharge temperature.
    - High bearing temperature.
    - Axial displacement.
    - Over speed.
    - Low fuel pressure or flame failure (for gas turbines).
    - High case temperature (for large electric motor drivers).
    - Overload (for large electric motor drivers)

2.2.7 Heat exchangers

Different types of heat exchangers are:

- **Shell and tube heat exchangers:** shell and tube heat exchangers seldom have pressure relief valves for fire exposure because vapours will quickly flow to the next pressure vessel, from which they can be discharged.

  For relatively low-pressure equipment, complete tube failure is not a viable contingency when the design pressure of the low-pressure side is equal to or greater than two-thirds the design pressure of the high-pressure side. Minor leakage can seldom result in overpressure of the low-pressure side during operation.

  If the above rule is satisfied, then a relief valve on the low-pressure side of the exchanger is not needed provided the following contingencies are true:

  1. An engineering study is performed to verify that the low-pressure side of the exchanger is

able to absorb the flow rate through the rupture without over-pressuring the exchanger.

2. There are no block valves, check valves, or automatic control valves on the low-pressure inlet or outlet piping systems that may isolate the exchanger.
3. Operating procedures require that the high-pressure side be isolated before the low-pressure side and that the exchanger be immediately drained upon being removed from service. Also, the exchanger must remain drained while it is out of service.
4. The valve isolating the vessel and the exchanger will generally be a horizontal stem and manually operated gate that is locked open.
5. The hot-side fluid is not hot enough to boil the cold-side fluid at the design pressure. Shell and tube exchangers do sometimes have thermal relief valves to protect against over-pressuring the cold side.

Shell and tube exchangers do sometimes have thermal relief valves to protect against over-pressuring the cold side.

- **Air-cooled exchangers:** An air-cooled exchanger generally has a fan that forces air across the tubes that contain the process fluid that is to be cooled. Air coolers in hydrocarbon service are susceptible to severe fire damage because the draft created by the fan pulls up heat from fires that occur at a lower elevation. This risk can be reduced by locating equipment with high-potential fire risk such as pumps and compressors away from overhead air coolers.

  Fan failure can cause extreme vibration resulting in line flange leaks. Also, failed fan blades can damage piping and endanger personnel. Vibration switches that can be set to shut the fan down before vibration reaches a destructive level are recommended for all air coolers. Also, limiting the maximum tip speed to 50 m/s will decrease the vibration and noise levels of the air cooler.

- **Cooling towers:** Cooling tower failure or loss of cooling water flow can lead to emergency shut downs and the potential for hydrocarbon leaks and fires. Consequently, spare cooling water pumps should be provided and their drivers (either electric or steam) should be very reliable.

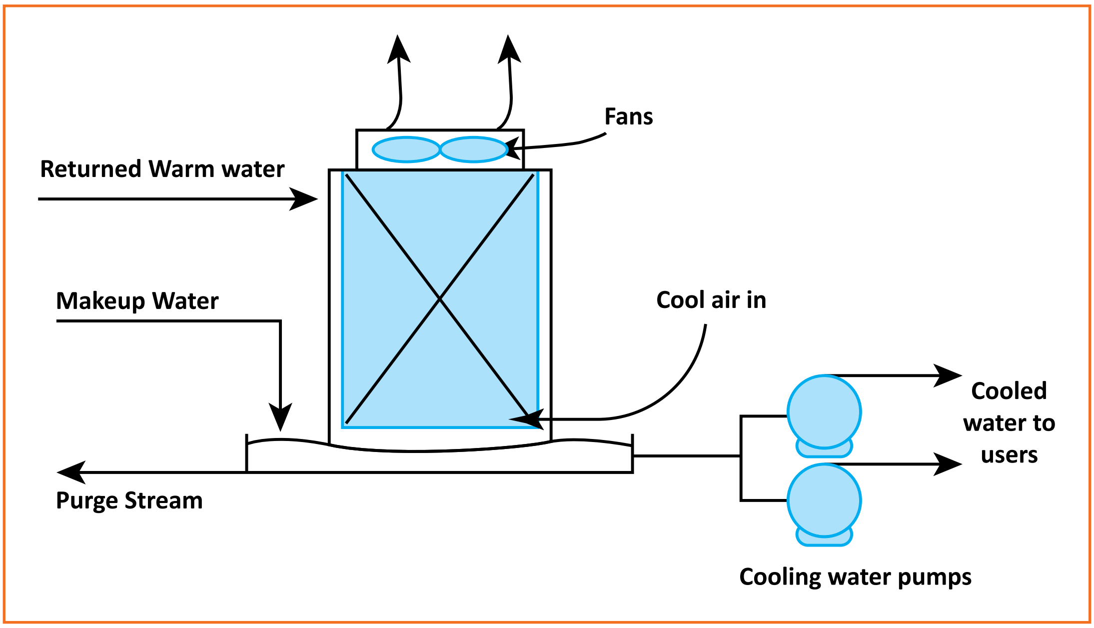


Fig: 2.2.3 Cooling Tower

If a heat exchanger that uses cooling water experiences an internal leak, either in one of the tubes or at the tube sheet, and if the process pressure is greater than the cooling water pressure, then flammable materials will enter the cooling water. They will then go to the cooling tower where they will evaporate and possibly catch fire. Therefore, where possible, heat exchangers that use cooling water should have a higher pressure on the water side than on the process side. Then, if there is a leak, water will enter the process stream. In general, this is a less hazardous situation than that where hydrocarbons enter the cooling water.

To minimize potential problems with hydrocarbon in cooling water, the following precautions should be taken when designing cooling towers:

1. Cooling towers should be electrically classified. Fan motors, pump motors, and other electrical apparatus should meet class 1, division 2 requirements.
2. Cooling towers should be located away from process equipment and furnaces.
3. Disengaging standpipes or chambers should be installed on the water return line to the cooling tower to release gases before the water reaches the tower water distribution system.
4. The cooling water pumps and their switchgear should be located at least 3 meters from the base of the cooling tower.
5. The fill material in the tower should be non combustible.
6. Two manual shut off switches for fans should be installed at the cooling tower, one at grade and one at the top deck. Vibration cut out switches should also be installed.
7. A hydrocarbon detector should be placed in the cooling tower plume. This will notify the operators that there is a leak in the system (although it can be difficult to know which particular equipment item is leaking.
8. Hydrants with monitors should be spaced such that any area of the cooling tower can be covered by streams from at least two directions

2.2.8 Fired heaters

Fired heaters transfer heat directly from a flame to a process fluid that usually flows through a set of tubes. They are used when the process material has to be heated to a high temperature. Some operational and safety considerations to do with fired heaters are discussed in this section.

Start-Up of Fired Heaters

The lighting of fired heaters has the potential to create an explosion. Two issues are of particular concern. The first is that the firebox is filled with a flammable mixture of hydrocarbon gas and air (oxygen). If a burner is ignited, an explosion will occur. The second concern is that a furnace is operating normally, and then the fuel gas supply fails thus causing the burner flames to go out. If the fuel gas supply is then restored, an unburned mixture of gas and air can enter the hot fire box and ignite.

Conditions under which furnaces are safe to operate can be deceptive in appearance. They look dangerous when they are in operation, and they appear to be harmless when not in operation. Actually, a furnace may be most hazardous when it is inoperative or in a turn down condition where flame outs can occur resulting in unlit fuel gas filling the firebox. This situation can lead to an explosion when attempts are made to light or relight a furnace. Most furnace explosions occur when burners are being lighted and result from failure to adequately purge the firebox. Incidents are 10 times more likely to occur during a start-up especially after an abnormal shut down. The following guidance to do with the start-up of fired heaters is provided.

- Temporary or unusual furnace operation shall be addressed in written procedures to reduce the risk of flame out in the furnace.
- After a unit shut down.

    1. Furnace fuel gas and pilot gas systems shall not be put into service until.
    2. Immediately before the furnace is to be lighted.
    3. Fuel gas lines shall not be purged into the firebox unless sufficient draft.
    4. Has been established.
    5. Fuel gas lines are checked to be liquid free.
    6. Burner and pilot gas valves are fully closed before pulling blinds.

    All air doors and stack dampers should be wide open prior to purging the furnace. Primary air registers on premix gas burners should be closed prior to lighting to prevent flashback.

- A visual inspection of the firebox must be done prior to lighting to ensure that all debris or flammable materials are not present.
- Immediately prior to lighting pilots or burners, the firebox must be purged, generally either steam or air from the furnace fans. Ensure that the entire furnace is purged of hydrocarbon and a draft is established. Adjust the main stack dampers to always provide adequate draft during the lighting process.
- If igniter are not available, an approved gas torch can be used.
- Strong winds can cause increased draft in upwind burners. Wind direction should be considered when lighting pilots and burners.
- Each flame must be stable before the next burner is lit.
- The person lighting a burner should always stand to one side so as to minimize the risk of injury from blow back.
- Operating procedures must state the maximum amount of time allowed for the burner to light. If the burner does not light in the specified period, the gas flow to that burner should be stopped and the torch removed.
- The firebox must be re-purged before attempting to relight the burners.
- Process side flow is not required prior to lighting pilots because the heat generated from pilots will not damage furnace tubes. However, process side flow must be established prior to lighting any burners.
- For furnaces that are equipped with pilots, all operable pilots need to be confirmed lit before

lighting any main burner.

- Once the fuel ignites, open the primary air registers until the yellow flame turns blue. Do not blow out the flame by opening the register too much or too quickly. If a torch was used to light the burner, keep it in place until the flame is steady.
- Light each pilot or burner in the same manner as the first one. Never light one burner from another; to do so invites explosion. Increase the fuel gas flow with the control valve or control valve bypass to maintain steady gas pressure and stable flames. Inspect the firebox frequently. A lighted burner may go out in a cold firebox.
- After all burners are lit and in operation, if one burner goes out, shut off fuel to that burner for a minimum 5 minutes and then relight with a torch or the pilot.
- If the furnace is to be dried out after repairs, light pilots and burners in a stepwise approach according to special procedures. Furnace temperatures can reach as high as 120°C with just the pilots lit.
- If burners reach their minimum fuel gas flow, a flame out may occur. During turn down situations, typically all burners in a furnace do not need to be lighted. It is better to remove some burners from service and maintain the fuel gas control valve **"in control"** with the fuel gas block valve wide open than to operate all burners with the block valves pinched back. Low-NOx burners are particularly sensitive to turn down conditions.

Air pre heaters

Air pre heaters raise the temperature of the air entering burner system using hot exhaust gas. They generally fall into one of the following categories.

1. Rotary regenerative.
2. Tubular recuperative.
3. Plate recuperative.

The moving parts associated with the rotary type of pre heater make them more susceptible to a fire than the recuperative type.

The majority of the fires in air pre heaters result from combustible deposits that are carried by the flue gas into the pre heater and accumulate on heat-transfer surfaces. Fires are usually initiated by the deposited soot at a temperature within the normal operating range. The fire can be sustained from the oxygen in the iron oxide in the pre heater.

These self-sustaining fires are difficult to extinguish. Steam cannot be used because it will react with high-temperature carbon in the water/gas reaction to produce carbon monoxide, carbon dioxide, and hydrogen, along with large quantities of heat-thus increasing the extent of the fire and the resulting damage.

Water can be effective if deluge sprays are installed in all four sectors of the ducting of a regenerative type air pre heater, thereby completely blanketing the entire heat-transfer surface with water.

Fired heater burnout

Fired heaters rely on the flow of process fluids through the tubes to keep tube and firebox temperature down. If the temperature of the process fluid leaving the heater falls, the temperature indicator on the discharge stream calls for more fuel to be fed to the burners.

The difficulty with the above arrangement arises if the flow of process fluid is stopped for any reason the outlet temperature will fall, thus causing the flow of fuel to be increased. However, without the flow of process fluid, there is no means of removing the heat that is being added (rather like putting an empty kettle on a stove). Hence the tubes will get hotter and hotter until eventually they fail (or the catalyst that is in them is irreversibly damaged).

One solution to the above problem is to put a flow measuring device on the fluid stream. If the flow of process fluid falls below a threshold value, the heater will be automatically shut down.

2.2.9 Boilers

Boilers are subject to extensive code and regulatory requirements. All boilers should have the following minimum safety controls.

- A pressure relief safety valve capable of relieving overpressure at maximum heat input.
- Low and high water alarm, and low and high water alarm and interlock to shut off fuel input.
- Alarms and interlocks on airflow to shut off fuel supply in the event of forced-draft fan failure.

Gas-fired boilers should have the additional controls listed below. These controls should cause the safety shut off valves to close if a condition they monitor deviates from normal, which are as follows:

- Low and high gas pressure switches.
- Main burner and pilot double-block-and-bleed safety shut off valves.
- Flame failure scanners with the time-limiting **"trial for ignition"** feature included in the circuitry.

On boilers with under boiler air ducts, faulty or plugged fuel oil burners can cause fuel oil to back up into the air ducting where it will accumulate and burn. Provision for injecting fire foam or steam should be provided.

2.2.10 Internal combustion engines

Internal combustion engines have many applications in both stationary and mobile equipment, but these are the sources of ignition when exposed to a flammable mixture of hydrocarbon vapour. Types of internal combustion engine found in the process industries include the following.

- **Large stationary engines:** Commonly used as gas-fuelled drivers of large compressors or pumps.
- Intermediate size stationary engines fuelled by gas, gasoline, diesel, or LPG and used to drive pumps, compressors, generators, mixers, and other equipment.

- Mobile engines fuelled by gasoline, diesel, or LPG and used to drive mobile equipment including cars, trucks, cranes, forklifts, pumps, generators, and front-end loaders.

Cars, trucks, and other motorized vehicles normally used for highway transportation should not be permitted to enter process units, tank farms, and restricted locations until the area has been checked with a combustible gas indicator to ensure that concentrations of flammable vapours do not exceed 25% of the lower flammable limit (LFL).

A modified internal combustion engine is less likely to be an ignition source than an ordinary engine. When special operating conditions justify modifying and maintaining this equipment, the recommendations of this section should be considered.

Where it is not practical or economical to modify a permanently installed internal combustion engine, an acceptable alternate is to provide adequate ventilation to prevent accumulation of hydrocarbon vapour in concentrations above 25% of the LFL. The engine may be enclosed in a pressurized area to exclude vapour or ventilated with an air sweep that will ensure vapour concentration will never reach the flammable range. Automatic shut down should be provided in the event of a ventilation system failure.

Generally, the fire loss risk should be evaluated on the basis of:

- The probability of a hydrocarbon vapour release near the engine.
- Characteristics of the engine (fuel and ignition systems).
- Existing fire protection facilities (equipment spacing, firewalls, detection, and extinguishing systems).

The same detection and control systems recommended for larger stationary gas-fuelled engines driving compressors and other equipment should be considered for other critical or high-risk equipment. Fire and combustible gas detectors should be employed to sound alarms or shut down operating equipment, shut off fuel supply, activate motor-operated valves to close all intake and discharge lines, relieve pressure to a vent stack, or activate fixed extinguishing systems. These detection systems are recommended for all critical unattended or not-regularly attended facilities.

For enclosed internal combustion engine facilities, the detection system should alarm and activate any emergency ventilation systems to keep air in the facility below 20% of the LFL. If the combustible levels continued to rise up to 60% of LFL, the detection system should activate further protections (e.g., Shutting down the ventilation and shutting down the engine). Another consideration should be the location of ventilation exhausts with respect to outside ignition sources.

Fixed fire control systems such as fire water monitors or water sprays over critical or high-risk equipment or carbon dioxide flooding of enclosures should also be considered. Except for combustion gas turbine enclosures, situations warranting such protection are not common.

Starter systems

The starter system can be electrical, pneumatic, hydraulic, spring recoil, or inertia. It may be acceptable to use an electric starter motor that does not meet the area classification requirements if proper entry permits are used and one of the following criteria is satisfied.

A lockable switch is provided so that the electric starter motor can be locked out to prevent its use in a classified area.

- The starting battery is kept outside the classified area and the engine is started there.
- The starter, the starter motor switch, and the solenoid are inspected to be sure they are not an open device.
- The starter motor should have a tight fitting cover band with a gasket installed to shield commutator arcing.
- The starter motor switch should have a tight fitting cover or the switch cover.
- Terminals should be covered with protective boots to avoid accidental shorting.

Large internal combustion engines are often started with air. This air is provided by a compressor-typically a conventionally lubricated reciprocating machine-and then piped to an air distributor on the engine. Explosions can be caused if combustible lubricant is present in the air. Therefore, non-combustible lubricants should be used.

Intake, exhaust, and fuel systems

The following guidelines apply to intake, exhaust, and fuel systems:

- Combustion air for all internal combustion engines should come through filtered air intakes. Engine exhausts should extend above the eaves of the building. The exhaust system for stationary engines with higher risk exposures should be leak-tight so flames from a backfire cannot escape, and they should be equipped with a spark-arresting type of muffler.
- Fuel lines should be of steel tubing or piping with flexible steel or steel-braided tubing sections where necessary to absorb pipe vibration. They should be located with at least 50 millimetres clearance from exhaust and electrical systems.
- Fuel lines, valves, fittings and vents should be located so that leakage will not drip on electrical or exhaust systems. Steel shut off valves located for access in time of fire should be provided in main fuel lines.

2.2.11 Electrical equipment

The following general guidance applies to the design and operation of electrical devices:

- All equipment should be properly insulated.
- Consideration should be given to the heating effects of the electrical circuits.
- All splices and joints and the free ends of conductors should be covered with an insulating device suitable for the purpose.
- Parts of electrical equipment which, in ordinary operation, produces arcs, sparks, flames, or molten metal should be enclosed or separated and isolated from all combustible material.
- Equipment should be properly labelled with information to do with the manufacturer, voltage, wattage, and other ratings.
- Each service, feeder, and branch circuit should be legibly marked to indicate its purpose.

- Each means for disconnecting motors and appliances should be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident. These markings should be durable.

Electrical equipment in process facilities is often exposed to rain and process fluids. Therefore it is important to use ground fault circuit interrupters (GFCIs) in these situations. These are devices that will trip and disconnect a circuit when the leakage current to ground exceeds approximately 5 milliamp below any personnel hazard level. The speed of response generally is less than 0.05 Seconds for 15-20 amp units. GFCIs should be used for the following applications.

- All 120-volt single-phase 15 and 20 amp outlets that are not part of the permanent wiring of a building or structure (e.g., Temporary wiring during construction).
- Wash room and change room outlets.
- For all areas with moist or wet ground where electrical equipment or portable electric tools are likely to be used.
- Areas where portable electric tools are used regularly, such as in plant shops, or during maintenance

2.2.12 Piping and valves

Many of the general comments made with respect to the safety and operation of pressure vessels apply equally to piping and valves. Indeed, a pipe is, in effect, a pressure vessel. Also piping, valves and flanges must meet the requirements for safe operation at operating temperatures and pressures, and must be chemical resistant to the liquids and gases that go through them.

Piping

When designing, operating, and maintaining piping issues to consider include materials of construction, insulation, and the selection of gaskets.

Materials

Steel piping is widely used due to its strength, flexibility, ductility, and weld ability. However, steel may not be practical for some acids, chemicals, or for use at high temperatures. Seamless steel pipe affords maximum fire safety. Steel is often used in lines carrying water or steam where failure at times of fire could interfere with fire fighting activities. Steel should also be used for valves, flanges, and fittings, because of its superior ability to tolerate thermal shock, bending loads, and hydraulic/mechanical shock.

Welded joints in steel and steel alloys are more likely to remain tight through a fire than any other type. In large-size pipes, welded joints cost less than screwed or flanged joints and should be used in all cases except where the installation of slip blinds requires the availability of flanges.

Cast iron is less expensive and in some cases more corrosion resistant than steel. Nevertheless, the use of cast iron pipe is undesirable in oil or gas service because of its brittleness. If heated by fire exposure and then quenched it can fail. Rubber, neoprene, plastic, aluminium, brass, and other low melting point materials should not be used for hydraulic or lube oil piping. A small fire near these materials will cause them to fail quickly with the potential to release large volumes of oil into the fire.

Piping made of brass, copper, or aluminium is sometimes used for special purposes. These metals have low melting points and thus have a high potential for failure if exposed to fire. Alloy materials are sometimes chosen for severe temperature or corrosion services.

Insulation

Pipe insulation should be non combustible. Where hot piping insulation can be exposed to hydrocarbon leaks it should be provided with metal weather jacketing because oil soaked into the insulation can auto-ignite at line temperatures as low as 175°C.

Gaskets

For the majority of moderate-temperature services, composition gaskets on raised face flanges are acceptable. At flanged joints where additional reliability is desired or for higher temperatures, spiral-wound gaskets on raised face flanges should be used. For services with special temperature, pressure, or chemical hazard problems, a ring-type joint or equivalent should be considered.

Thermal expansion

Hot process lines need to be able to handle thermal expansion; even with lines expected to operate at normal temperatures it is desirable to provide sufficient flexibility for expansion and contraction caused by changes in atmospheric temperature, possible fire exposure, steam out, and pump out. Flexible couplings may fail rapidly under fire exposure and should be avoided wherever possible in systems handling hydrocarbons. The use of offsets in welded pipe is much safer.

Provision should be made to relieve excess pressure developed in lines due to the thermal expansion resulting from temperature changes. Relief valves should be installed on all lines that can be blocked and where no valve leakage is expected, and on lines confined by valves where leakage past the valve can be expected, but where there is more than around 60 meters of pipe per valve.

Identification and labelling of pipes

Piping that is either partially or wholly exposed should be identified by legends that include the safety colour code, pipe contents, flow direction arrows, and to/ from information.

2.2.13 Blinds

Blinds, also known as blanks or spades, Blinds provide positive isolation between sections of a process. The following guidance is provided to do with the location, installation, and use of blinds.

- At battery limits in all process, utility, relief, and blow down lines.
- As required for inspection, maintenance, testing, or alternative operation of equipment, such as vessels, heaters, rotating equipment, or exchangers.
- Where segregation of fluids is required.
- Blinds should be installed in horizontal lines where possible. Doing so makes handling and

installation easier and reduces the chances of damaging the gaskets during installation. Also, blinds in vertical lines may trap liquid above them. For this reason, blinds should not be used in vertical water or steam lines where there is a potential for freezing.

- Blinds for rotating equipment and the tube side of shell-and-tube heat exchangers should not be located at the equipment flanges.
- Piping at locations where blinds and their associated spool pieces should be arranged so as to permit the removal of the bolting for the blinds, and to allow space for swinging the blind once it is unbolted. Sufficient space should be provided not only to insert the blind but also for the equipment needed to lift the blind into place.
- Supports to maintain piping alignment when blinds are being installed or removed are required if the piping or other items, such as valves, are located at or near the blind location.
- When it is expected that a blind will be inserted and removed on a regular basis, platforms should be provided.
- Permanent handling equipment shall be provided for all blinds weighing more than 45 kg (100 lb).

Most blinds are either of the line or spectacle type.

Line blinds

A line blind: Also known as a spade, paddle, skillet, pancake, or slip blind-consists of a solid metal disk with a thin length of metal attached to it. The metal of the blind should be rated for full process pressure on one side and atmospheric pressure on the other side. The handle should be long enough so that it can be seen through insulation and any other materials that might be covering the flange.

Spectacle blinds

If a flange is to be routinely blinded, a spectacle blind, disk-and-donut, or spec blinds) can be installed. This type of blind looks like a pair of spectacles or the number 8, with one section closed and the other open. When the flange is broken and the line cleared, the blind can be rotated around the one bolt that.

Is left in the flange. It is simple to ensure that the blind has been installed because the open part of the blind will be sticking out from the flange face. If spectacle blinds in horizontal pipes are insulated, the blind should point downwards at an angle of 45° to avoid water leaking into the insulation.

2.2.14 Valves

Valves are used to stop and/or control the flow of fluid in piping systems. The different types of valve and their uses are discussed below.

- **Block valves:** block valves are, as their name suggests, valves that are used to totally stop the flow of liquid or gas through a pipe. They are generally either open or closed and should not be used to control the flow of fluid. They can be either manually operated or, in the case of large valves, opened with a motorized assist.

  Different types of block valve include gate, ball, butterfly, plug, and needle valves.

- **Valve seat material:** When exposed to fire, rubber-like, or teflon materials used for sealing, valve seats will fail faster than the valve metal. Therefore, all ball valves, plug valves, and valves that depend on o-ring stem seals in liquid hydrocarbon service should be designed so that failure of the seat material will not cause more than minor leakage past the ball, plug, or stem.
- **Self-closing valves:** Self-closing valves are used where failure to close a valve manually might permit flow of oil or gas into areas where a serious fire may result. The types of installation for which self-closing valves should be considered include water and chemical draws, vents, bleeders, drains, level cocks, sample points, and tank truck and barrel filling and emptying systems.
- **Check valves:** A check or non return valve is a commonly used safeguard to prevent the fluid back flow. It is, however, liable to failures such as the following.

  1. Solid deposits wedge themselves into the check valve's mechanism such that it does not close on demand.
  2. Corrosion products prevent the flapper from closing.
  3. The flapper fails to seat properly, thus allowing some leakage.

  For these reasons, check valves are normally regarded as being only a weak safeguard and should not be relied upon in critical service. As one hazards analysis leader has said **"if you rely on a check valve to be safe, then you're not safe."** Another leader uses a figure of 49 in 50 for check valve reliability in clean service, i.e., He anticipates that a check valve will not work on demand 2% of the time.

- **Emergency isolation valves:** If there is a serious fire on a unit, it may be impossible for the operators to reach the valves that must be closed to stop additional flammable material from feeding the fire. Therefore, it is useful to have emergency isolation valves (EIVs) at the unit's perimeter. If these valves are closed, the flow of all hazardous chemicals into the unit will be stopped and the fire will go out once the inventory of material within the unit has been consumed. The EIVs must be located and protected such that they are not damaged in a fire or explosion, and operators can reach them in an emergency. EIVs can be either manual or automatic. If they are automatic it must also be possible for the operators to reach them in an emergency and to close them by hand.
- **Excess flow valves:** Excess flow valves shut when the flow rate exceeds design flow rates. They are frequently used on hoses. However, they are not generally used emergency shut down or on storage vessels, loading points, or multi product systems, since they are not sufficiently reliable.
- **Trapped liquids:** Valves used in hydrocarbon liquid service should not trap liquids in their bodies. The liquid could expand during a fire and overpressure the valve body. Standard gate valves are normally not a problem because excessive pressure can be relieved by minor leakage past the valve seat. However, valves such as the **"double- block and bleed"** type will trap liquid. When these valves are used in liquid service, body relief valves are needed.
- **Plugs:** Steel plugs should be installed in all open-ended valves when not in use. Vents and drains should be routed away from the pump. In clean services, restriction orifices can be installed on root valves under pressure gage and pressure transmitter connections to minimize the release if damage to the gage or pressure lead occurs.

Plug cocks have been known to trap liquid inside the plug and bonnet area and cause potentially serious releases during maintenance.

2.2.15 Pressure relief devices

Pressure relief systems usually represent the last line of defence. This means that these systems should never actually be called upon to operate-high-pressure events should be handled by other safeguards in the lead-up to the event. But, if the pressure relief system is needed, then it must work. Hence the quotation **"relief valves must always work; relief valves should never work."** For this reason many companies require that, if a pressure relief valve opens during a high-pressure excursion, then a full incident investigation must be carried out since the last line of defence had to be used.

Design parameters

The following types of pressure relief device are discussed in this section:

- PSRV.
- Thermal relief valves.
- Rupture disks.
- Hatches.

Regulations and standards

Because relief valves are so critical to safe operations, many standards and rules have been written to do with their design and operation.

Causes of a relief valve not opening at its set pressure can include corrosion of the internals or plugging of the valve inlet or outlet with deposits.

Pressure safety relief valves

Pressure safety relief valves (PSRVs), frequently cross systems boundaries, i.e., They protect more than one process section. The scenarios to consider for isolation here are; when the equipment the PSV is protecting needs to be worked on or the PSV itself needs to be removed and worked on. Each PSV will have an isolation valve both upstream and downstream of the PSV.

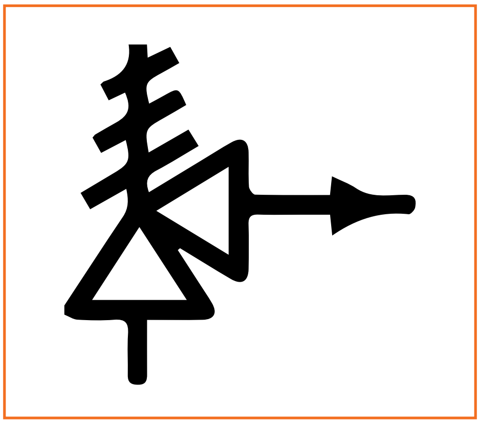


Fig: 2.2.4 PSRV symbol

When the equipment the PSV is protecting needs to be worked on, the pressure will be bled off the equipment and both upstream and downstream PSV isolation valves will be closed, the piping bled off, and a spade will be installed ahead of the upstream PSV isolation valve. The same procedure applies where there are dual PSVs in parallel.

When the PSV needs to be removed and worked on, the equipment the PSV is protecting will be shut in, both PSV isolation valves will be closed, the equipment will be de-pressurised, the PSV removed, and blinds installed on both open ends of the isolation valve flanges. Where 100% online capacity can be maintained while working on a parallel PSV, and the PSV can be safely isolated (risk assessment performed), shutting in the equipment, and de pressurising is not required.

The PSVs themselves are not considered as isolation valves for system or component isolation.

Pilot-operated pressure relief valves

The disk in a normal relief valve is kept in the closed position during normal operations by the force of a spring. A pilot-operated relief valve (PORV), however, uses system pressure to seal the valve.

The pilot valve allows the pressure in the dome to be equalized with the main system pressure. The area of the top of the piston in the dome is greater than the area on the system side so, even though the pressures on each side are the same, the downward force is greater than the upward force so the piston is held in place. If the system pressure rises above the safe limit the pilot valve opens and allows the gases in the dome to be vented to atmosphere or a relief header. The piston then opens and system gases flow out of the vessel being protected. To prevent excessive forces on the discharge piping, the pilot can be designed to open gradually such that the piston lifts in proportion to the degree of over pressure.

PORVs have the following advantages over standard pressure relief valves:

- For larger pipe sizes the relief system is smaller.
- There are more options for control.
- The system seals more tightly when system pressure approaches, but does not exceed set point pressure.

However, they tend to be more expensive for small valve sizes and the pilot valve is sensitive to contaminating particles (a filter screen should be provided on the inlet to each pilot).

Testing and inspection

All relief valves must be inspected on a regular basis. Indeed, such inspections are often mandated by regulation, e.g., For boiler service. Generally, the relief valve is removed from the vessel that it is protecting and tested in a workshop. The test will ensure that the relief valve opens at the specified pressure. Ideally, the test should also check the volumetric capacity of the valve. During the test, an inspection should be carried out to check for corrosion, physical damage, and any other problems that could affect the integrity of the relief valve. A representative testing is shown below.

- 30% Annually.
- 60% Every 2 years.
- 10% On an individual schedule.

The following list provides an example of guidelines used for testing relief valves.

- Components of pressure relief valves should be hydro statically tested before assembly. Parts made from forgings or bar stock are exempt.
- A specific inspection frequency shall be established for each safety relief valve. The inspection frequency will be a function of inspection history, relief system design, process conditions, operating experience, on-stream service capabilities, economics, and regulatory mandates.
- The maximum interval between inspections shall not exceed 10 years.
- The interval between inspections may be increased (not to exceed 10 years) based upon observed conditions at the time of shop inspection, engineering review, and reliability improvements.
- If a rupture disk is installed to isolate the relief valve from a particularly corrosive process, and the integrity of the rupture disk is known to be good, the interval between inspections may be increased. The rupture disk integrity must be verified via checks for pressure between the rupture disk and relief valve.
- If the relief valve has bellows to isolate the spring and close clearance parts from the downstream process, and the integrity of the bellows is known to be good, the interval between inspections may be increased. The bellows must be vented in normal operation (at atmospheric pressure). The integrity of the bellows must be verified via on-stream bellows testing.
- If a purge medium is used to minimize exposure of the relief valve internals to process fouling or corrosion, the interval between inspections may be increased.
- If materials of construction are selected such that corrosion will have minimal effect on the spring and valve trim, the interval between inspections may be increased.
- The interval between inspections must be decreased when service records indicate that the relief valve was heavily fouled or inoperative at the time of the last inspection or test.
- An online test may be used as the basis for extending the inspection interval to coincide with a planned outage provided the valve pops and resets at the proper settings. However, online testing cannot be substituted for a regular shop inspection and repair, nor can it be used as the basis for a permanent increase in the inspection interval.
- A relief valve must be removed from service for inspection and repair after an online test if it fails to open at set pressure or the valve chatters, or if it fails to reset properly.

2.2.16 Engine

Diesel

Unless otherwise specified the engine should be diesel and should have horsepower, torque, and speed characteristics to meet and maintain all specified vehicular performance characteristics in this standard. The engine manufacturer should certify that the installed engine is approved for this application.

Fuel systems

The fuel system supplied by the engine manufacturer should be of sufficient size to develop the rated power. The manufacturer should supply fuel lines and fuel filters in accordance with the engine manufacturer's recommendations. To prevent engine shut down due to fuel contamination, dual filters in parallel, with proper valves so that each filter can be used separately, may be desired.

Fuel tanks should not be installed in a manner that permits gravity feed.

A dry type air filter should be provided. Air inlet restrictions should meet the engine manufacturer's recommendations. Air inlet should be protected to prevent water and burning embers from entering the air intake system. The manufacturer should provide an air restriction, indicator, mounted in the cab, visible to the driver.

An engine governor should be installed which will limit the speed of the engine under all conditions of operation to that speed established by the engine manufacturer; this should be the maximum no-load governed speed. A tachometer should be provided on the instrument panel in the driving compartment for indicating engine speed.

Gasoline engines

Fuel lines and filters and/or strainers of an accessible and serviceable type, as recommended by the engine manufacturer, should be provided. The filters or strainers should be of a type, which can be serviced without disconnecting the fuel line. Where two or more fuel lines are installed, separate fuel pumps operating in parallel with suitable check valves and filtering devices should be provided. The fuel line(s) should be so located or protected as not to be subjected to excessive heating from any portion of a vehicle exhaust system. The line(s) should be protected from mechanical injury. Suitable valves and drains should be installed. The carburettor(s) of a gasoline engine should be non adjustable, with the exception of the idle setting, of sufficient size to develop the rated power, and so located as not to be subjected to pocketing of vapour or excessive heating. An automatic choke should be provided. The gasoline feed system should include an electrically operated fuel pump located within or adjacent to the fuel tank.

Fuel tank

For light vehicles, the fuel tank should not be less than 100 l capacity. The capacity for apparatus with pumping equipment should be of a size, which should permit the operation of the pumping for not less than 3 h when operating at rated pump capacity. A suitable method of venting and means for draining directly from the tank should be provided. The tank fill opening should be conspicuously labelled as to the type of fuel used.

When a large capacity fuel tank is desired the capacity specified by purchaser in special provisions should be supplied.

Only one fuel tank is to be furnished where rated tank capacity is 150 l or less. The fuel gage should indicate the proportionate amount of fuel in the tank system at any time.

Tank and fill piping should be so placed as to be protected from mechanical injury, and not be exposed to heat from exhaust or other source of ignition. Tank should be so placed as to be easily removable for repairs.

Automatic engine shut down systems should not be provided, but auto over speed protection by means of a shut-down valve in the air intake system in case of ignition of flammable gases should be provided.

The engine should be air cooled.

If the engine is subject to pump thrust, roller thrust bearing should be provided. Engine electrical components and ignition exposed to the weather should be protected from water. A rope, crank, or other manual starter should be provided.

2.2.17 Process hazards

High flow

Generally, the phenomenon of **"high flow"** - in and of itself - is not inherently hazardous. Indeed, high flow rates are often desired because they imply that the facility is maximizing production and revenues. Although high flow can occasionally create hazards, such as erosion of pipe walls or of a valve seat, its main effect in terms of process safety is to create secondary deviations such as **"high level"** in a tank. **"High flow"** can also create a **"no flow"** situation; e.g., If a pump over speeds, the sudden surge in motor amperage may result in the motor burning out, thus leading to the flow stopping.

Low/no flow

As with **"high flow,"** the phenomenon of **"low flow"** is not usually inherently hazardous. However, it can create secondary effects. For example, a low flow of cooling water in a heat exchanger can lead to **"high temperature"** of the process stream. **"No flow"** is usually more serious than **"low flow"** because its occurrence implies a sudden cessation of a processing activity. Probably, the biggest hazard associated with **"no flow"** is the possibility of it being followed by **"reverse flow"** because the upstream and downstream pressures have equalized or even reversed.

Both **"low flow"** and **"no flow"** are usually caused by the inadvertent closing of a valve or the failure of rotating equipment such as pumps and compressors. Because such events occur quite frequently, most facilities have plenty of instrumentation and safeguards to respond to these scenarios.

Reverse flow

"Reverse flow" can create high-consequence hazards because it can lead to the mixing of incompatible chemicals or to the introduction of corrosive chemicals into equipment not designed for them. The cause of **"reverse flow"** is usually a pressure reversal - a high-pressure section of the process loses pressure; process fluids then flow into that section back from low-pressure sections of the process.

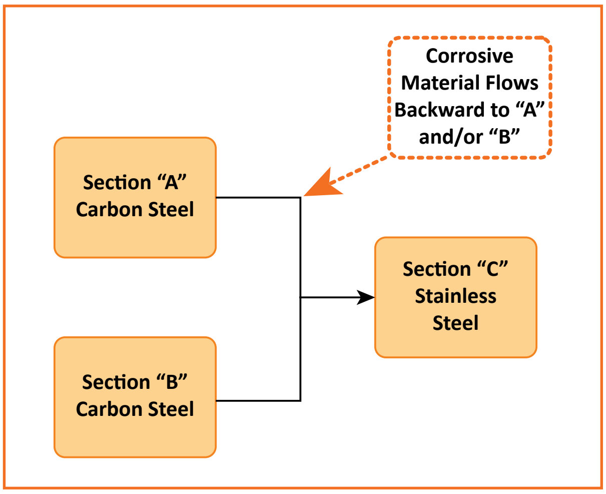


Fig: 2.2.5 Reverse flow scenario

(The occurrence of reverse flow almost invariably implies that a check valve and/ or safety instrumented system has failed to prevent the event).

"Reverse flow" can lead to "contamination." A process consisting of three sections: a, b, and c. The chemicals in sections a and b are non corrosive, so these two sections can be safely made of carbon steel. When the two chemicals are mixed in section c they react to form a corrosive product, hence this section has to be made of stainless steel. If a reverse flow should occur from section c to either a or b, then those sections would corrode, leading to loss of containment.

Another feature of **"reverse flow"** to watch for is that it may take some time for the operators to identify its occurrence, particularly if the flow measurement instrumentation is not set up to recognize the phenomenon. Moreover, experienced operators frequently have trouble visualizing **"reverse flow."** They recognize the possibility of high and low flow because they have probably witnessed these events but reverse flow may be totally outside their experience.

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Misdirected flow

"Misdirected flow" occurs when a process stream is sent to the wrong destination. Like **"reverse flow,"** this deviation can create high-risk scenarios because incompatible materials may be mixed with one another, or corrosive chemicals may be sent to areas not designed for them. Also like **"reverse flow,"** this scenario may be difficult to detect or diagnose.

High pressure

"High pressure" is a cause of many serious events. For **"high pressure"** to create an incident, it is likely that a protective interlock system failed and/or that the system's pressure relief valves did not function properly. The worst case is selected for the design of the relief device.

One special cause of high pressure is the explosion caused by near instantaneous evaporation of liquid through contact with hotter liquid. This may occur, for example, if very cold LNG (liquefied natural gas) comes into contact with water. The very high LNG vaporisation rate can lead to an explosion. Such an event could occur during LNG transfer between an onshore terminal and the LNG carrier.

High temperature

As process temperatures increase the metal walls of pressure vessels will weaken thus reducing the maximum allowable working pressure (MAWP). (If the equipment of piping is made of synthetic materials, high temperature may lead to a sudden failure.) Hence a very high temperature, such as would occur in a runaway reaction, could lead to vessel failure at quite low pressures. Therefore, MAWP values should always be quoted with a corresponding temperature value.

Some causes of high pressure

External fire impacting a vessel or piece of equipment.

- Low flow out of a vessel.
- High flow into a vessel.
- Chemical reaction inside a vessel.
- Blocked outlets.
- Blocked-in pump.
- Blocked-in compressor.
- Connection to a higher pressure system and control system failure.
- Overfilling of storage or surge vessels.
- Utility failure.
    - Electric power.
    - Instrument air.
    - Cooling water.
    - Steam.
    - Fuel (gas or liquid).
- Loss of cooling capacity.
- Loss of quench.
- Loss of absorbent flow.
- Failure of air-cooled heat exchanger.
- Failure of water-cooled heat exchanger.
- Cold side of an exchanger blocked in while the hot fluid continues to circulate.
- Failure of heat recovery system.
- Loss of cold feed.
- Failure of the flow of reflux or a side stream to a tower.
- Excessive heat added.
- Exothermic reaction.
- Abnormal vapour input.

Blocked-in pump.

If a centrifugal pump is blocked in while it is still running the liquid trapped within the pump will heat up due to the energy that is being added by the rotating impeller. Sometimes, the rise in temperature will cause the pump seal to leak thus dissipating the pressure at the pump without creating a major hazard. In rare cases, however, the liquid in the pump may boil or react, thereby generating sufficient pressure to rupture the pump casing.

Low temperature

"Low temperature" usually does not represent a safety threat to a process. Like **"low flow,"** a reduction in process temperature will often lead to production losses, but rarely to unsafe operations.

Low boiling point liquids may cause auto-refrigeration during emergency venting. Propane boils at approximately 243°C and ethane at 285°C. Since ordinary carbon steels become brittle at these temperatures de-ethanisers, de-propanisers and vessels containing similar liquefied gases may require special low temperature steels to withstand auto-refrigeration temperatures associated with emergency venting.

Embitterment problems can be addressed by using a higher grade of steel. Equipment in cryogenic service and with heat-sensitive insulation should be protected with fireproofing insulation to keep heat-sensitive insulation below degradation temperature.

High level

The deviation **"high level"** is important, particularly with regard to storage tanks, because it can lead to an immediate overflow of a hazardous chemical on to the ground or into a drain system. A particular difficulty with this deviation is that there is often little guidance as to the value for the safe upper limit. Sometimes, operations management will choose to run a tank up to almost 100%, even though the chance of a spill becomes high.

A second issue regarding high level is that many tanks are not adequately instrumented and may lack automatic alarm or interlock functions.

Corrosion

Corrosion can be either uniform or localized. Uniform corrosion occurs evenly over a large metal surface and can involve large metal loss; hence, the equipment involved may lose a considerable amount of mechanical strength. Localized corrosion is evident through the appearance of pitting and crevice attacks; it can lead to the creation of stress corrosion points.

Uniform corrosion can usually be predicted and monitored. Therefore, even though the ultimate consequence associated with this type of failure can be high, it is unlikely to be a serious problem in practice because corrective action can be taken in plenty of time. Localized corrosion is more difficult to monitor and predict - thus it can often present a higher risk.

Static electricity

One of the hazards that must be guarded against in handling petroleum products is accidental ignition by static electricity. Tank car and tank truck loading operations involving distillate products, under certain conditions, are particularly vulnerable to static ignition

2.2.18 Hazards of utilities

Utility systems can create many difficult-to-predict hazards because they connect many different sections of a process.

Common cause failure

The first and most obvious problem to do with utilities is that their failure will create simultaneous problems throughout the facility. They generate common cause effects. For example, were oxygen to enter a nitrogen header a fire or explosion hazard could be created in other parts of the plant or facility.

Process contamination

A second, and more subtle, problem to do with utilities is their potential for process contamination. On one refinery, e.g., The highly toxic and corrosive chemical hydrogen fluoride (HF) leaked into the instrument air system. This had the effect of spreading HF all around the refinery; it was even being vented from instrument lines in the control rooms.

When a leak occurs between the process and one of the utility systems, it is often difficult to track down the source of the leak. For example, it is quite common to place a hydrocarbon detector in the plume from a cooling tower. Then, if one of the process coolers or condensers leaks, the detector will detect the presence of hydrocarbons. The difficulty lies in knowing which of the equipment items is leaking.

Electrical power failure

Failure of the electrical system can lead to **"high pressure"** in those cases where the utility is removing energy from the process. For example, an overhead fin-fan on a distillation column may serve to condense the overhead vapours from that column.

Loss of power will cause the vapours to pass through the condenser without being cooled or condensed, thus creating a high-pressure situation. Loss of power can also cause critical instruments to shut down. These instruments should be backed up with an uninterruptible power supply (UPS).

Nitrogen

Nitrogen has many uses on process facilities, including the inert gas blanketing of tanks, equipment purging, and as a carrier for catalyst regeneration. Oxygen contamination of the nitrogen system must be avoided as such because contamination could create a mixture that is no longer an inert medium.

Its availability in large volumes in many facilities also allows for its use as an emergency source of instrument air. However, this practice can have serious consequences. Instrument air systems often vent or leak into confined areas - the presence of nitrogen could create a serious breathing hazard. It is suggested that the following guidelines be considered when using nitrogen to back up the instrument air supply.

- Do not allow permanent connections between the nitrogen system and either the plant or instrument air systems.
- Utility nitrogen stations should be clearly marked and have special connectors and hoses which are not common to any other system. Universal air hose connections (crow's foot) should not be used in nitrogen service.
- Locations where backup nitrogen is being used should be monitored and alarmed for low oxygen concentration, and signs and barriers installed.
- Once the problem with the instrument air system has been resolved, the nitrogen to instrument air cross connection must be removed.

2.2.19 Hazards of steam

One of water's greatest hazards is the volumetric expansion (and corresponding pressure increase) that takes place when it is transformed into steam. For example, at its boiling point of 100°C water vapour occupies a volume 1,600 times that of the corresponding liquid. Many of the hazards of steam discussed below are so serious because of this very large volumetric expansion.

Steaming vessels during turnaround

After a piece of equipment, such as a heat exchanger or a distillation column, has been inspected or repaired, it is a common practice to steam out that item prior to its restart. The steam helps clean the metal surfaces of residual maintenance materials (such as oil) and also removes oxygen (air) from the vessel. On completion of the task, some of the steam that was present in the system will condense; the resulting water will collect at low points in the system, behind orifice plates, above horizontal valve bodies, in trap out trays, and in vessel bottoms. Where possible, low-point bleeders should be installed so that the trapped water can be drained.

However, it is not possible to place bleeders at all low points; also bleeders have a tendency to plug - particularly if they are only rarely used. Therefore, it is very likely that, on restart, the process will contain residual water at various locations. If heated by the process fluids, the water vapour that is formed could cause considerable damage. Moreover, if the water vapour then condenses in another part of the process a vacuum could be created with the attendant danger of implosion.

To reduce the hazards associated with water accumulation, a common practice is to start the commissioning process by circulating oil or hydrocarbon around and through all of the equipment, then gradually heating the circulating oil. Any water is swept out of the pockets where it has accumulated and gradually evaporated as the oil heats up.

Re-boiler leak

Many distillation columns are heated by steam re boilers. Typically, the process materials are on the tube side of the exchanger with the steam being on the shell side.

If the steam is at higher pressure than the process (which is frequently the case) and if one of the reboiled tubes develops a leak, steam will enter the process and flow up the distillation column. Given that the water has a much lower molecular weight than most chemicals that are being distilled, the volumetric flow of gas up the column can be so large that the trays or packing in the column are lifted up off their supports and seriously damaged.

Wet steam in turbines

Condensed steam must be drained from a turbine before it is put into service. Droplets of water moving at high velocities in a supposedly dry steam line can destroy a turbine or compressor wheel. Similarly, the presence of (incompressible) water in a reciprocating compressor can lead to the destruction of the machine.

2.2.20 Hazards of air

Because it is a substance that everyone breathes all the time, air is rightly perceived as being benign. However, air does pose some hazards on process units, mostly due to its oxygen content, which is an oxidant for hydrocarbons and other materials that burn. If air enters a process that contains flammable hydrocarbons and/or reducing chemicals, then a serious accident could ensue.

Flammable mixture

Air can enter a process in one or more of the following ways:

- Through open lines and vessels.
- With a process stream or with wash water.
- Leakage into vacuum systems - say through an open bleeder.
- Leakage through open or defective valves.
- Atmospheric air entering a vessel or tank when liquid levels are lowered.
- Compressed air leakage into a process from a compressor or blower.
- Compressed air used in line blowing.
- Compressed air used for agitation.
- Air in solution in feedstock or products.
- Failure to purge a system properly following a turnaround.
- Air used in oxidation processes.
- Air contamination of nitrogen or other compressed gases used for purging or processing.

Air dissolved in a hydrocarbon stream such as propane can be particularly dangerous. If the stream is pumped into a storage vessel, some of the propane and oxygen in the air will vaporize. Being more volatile than the hydrocarbon, the oxygen content in the vapour space will be higher than it is in the liquid. If some of the liquid is pumped out, and then replaced, the concentration of oxygen in the vapour space at the top of the tank will gradually build up - possibly to dangerous levels.

For these reasons, all vessels, which can have a vapour space in which air can accumulate, should be checked on a regular basis for oxygen. If significant oxygen concentrations are found to be present, then the vapour space should be purged with an inert gas such as nitrogen.

Blowing a line clear

If a pipeline becomes plugged with a solid obstruction, it can be blown clear with high-pressure gas. It is important not to apply too much pressure to the obstruction, otherwise, when it does move, it will become like a missile within the pipe. One company plugged a transmission line with hydrate. They then applied a very high pressure to the plug gage, with just atmospheric pressure on the other side. The hydrate plug did break free; it raced down the line, and then hit an elbow. Its momentum was so great that the elbow was ruptured, and a worker was killed.

2.2.21 Hazards of Equipment and Instruments

Furnace firing

The lighting of fired heaters always has the potential to create an explosion. Two issues are of particular concern. The first is that the firebox is filled with a flammable mixture of hydrocarbon gas and air (oxygen). If a burner is ignited, an explosion will occur. The second concern is that a furnace is operating normally, and then the fuel gas supply fails thus causing the burner flames to go out. If the fuel gas supply is then restored, an unburned mixture of gas and air can enter the hot firebox and ignite.

Fired heater burnout

Fired heaters rely on the flow of process fluids through the tubes to keep the tube and firebox temperature down.

If the temperature of the process fluid leaving the heater falls, the tic (temperature indicator controller) calls for more fuel to be fed to the burners.

The difficulty with the above arrangement arises if the flow of process fluid is stopped for any reason the outlet temperature will fall, thus causing the flow of fuel to be increased. However, without the flow of process fluid there is no means of removing the heat that is being added (rather like putting an empty kettle on a stove). Hence, the tubes will get hotter and hotter until eventually they fail (or the catalyst that is in them is irreversibly damaged).

One solution to the above problem is to put a flow measuring device on the fluid stream. If the flow of process fluid falls below a threshold value, the heater will be automatically shut down.

Multiple uses of equipment

When equipment items are used for more than one purpose there is a chance that a high-consequence hazard may be created. For example, on one plant certain storage tanks were used to store a liquid that could freeze at ambient temperatures.

Therefore, the tank contents were heated with internal steam coils. However, during turnarounds, the tanks were used to store another chemical. This second chemical was a monomer that could not freeze at normal temperatures and that could, if heated, polymerize rapidly and exothermically. Consequently, if during the plant restart the operators omitted to clear the tanks of this second chemical before turning on the steam coils, the chemicals in the tanks could polymerize, leading to an accident.

2.2.22 Hazards of piping, valves, and hoses

Piping

Hazards associated with piping include the following:

- **Pipe class transition:** When a pipe class changes, it is important to make sure that the lower grade of steel is not located too near the more severe service. For example, the transition from high temperature-to low temperature-rated pipe should not be so close to the higher temperature service such that the lower temperature line could be affected.

Similarly, it is important to ensure that hazardous chemicals cannot flow back into a lower pipe class zone.

- **Hydraulic hammer:** Hydraulic hammer is created by stopping and/or starting a liquid flow suddenly. If the valve in line containing liquid is closed quickly, the entire volume of liquid in the line up to the valve is also stopped quickly. The effect is to create a sudden pressure surge that can damage instruments and valves, and, in extreme cases, cause the pipe itself to burst.

  Hammer can also occur in lines containing process vapours or low-pressure steam. If the vapour or steam is cooled as it flows down the line liquid forms in the bottom of the line and then flows forward with the gas or steam. Eventually, the amount of liquid can be so great that it has the effect of blocking the line in the same way that a valve would do, thus creating the potential for hammer.

  If hydraulic hammer is considered to be a potential problem and the valve causing the hammer is automatically actuated, consideration should be given to putting a restriction in the vent line from the actuator. This restriction would prevent the valve from closing too quickly.

- **Overload of overhead vacuum lines:** High capacity vacuum distillation columns typically have very large diameter overhead lines from the top of the column to the condenser because the available pressure drop is so small. Also, because the system pressures are so low the piping wall can be quite thin. Therefore, if the line is inadvertently filled with liquid (either process liquids during a column upset or water during hydro testing) the lines or their supports could collapse.

  For these systems, special precautions need to be taken to ensure that the column cannot overflow. Also, a procedure for pressure testing the system with gas has to be developed and followed.

- **Underground piping:** Underground piping can be hazardous because not much may be known about the condition of the piping; **"out of sight, out of mind."** The first indication of a problem may be contamination of the groundwater or some other pollution event.

  Moreover, the piping may be subject to unusually high corrosion rates if a cathodic protection system was not installed.

- **Vents and bleeders:** A common hazard is the leak of a hazardous chemical from a vent or bleeder. Causes of the leak can include the following.

  1. The vent or bleeder is inadvertently left open (or not completely closed).
  2. The internals of the vent or bleeder valve erode or corrode, and leakage cannot be stopped.
  3. Someone working with the valve pulls it off the pipe to which it was connected (usually this requires corrosion to have weakened the join).

- **Hoses:** Hoses are often involved in accidents because, in almost all cases, their use implies that a temporary or short-term operation is being undertaken. Sometimes, the operation is routine - truck loading and unloading, for example. In other situations, hoses are used in temporary operations such as the bypass of a leaking valve that is to be removed for maintenance. Whatever the reason for its use, there is the potential for a release of hazardous chemicals, particularly at the start and finish of the operation.

- **Hose run over:** If vehicle runs over a hose that is in use, the hose may split. Alternatively, the hose may be crimped, leading to consequences such as low flow or high pressure in other sections of the process.
- **Hose failure:** Being flexible and subject to abrasion, hoses are subject to failure if not carefully inspected, maintained, and replaced. If hoses are to be stored outside, it should be confirmed that they cannot be damaged by water, freezing, or ultraviolet light from the sun.

Valves

Some of the hazards associated with valves are –

- **Block valves below relief valves:** Pressure relief valves are a critical safety item in almost all process facilities. Pressure relief valves simply must work. This means that they must never be blocked in from the equipment item(s) that they are protecting. Yet their very criticality means that relief valves will have to be routinely isolated and/or removed from the system that they are protecting so that they can be maintained and tested - both for the pressure at which they open and, more rarely, for their flow capacity.

  Therefore, many companies permit a block valve to be placed beneath each relief valve. This allows them to block in the relief valve, remove it for testing and service, and reinstall it, without having to shut down the process. The hazard associated with this practice is obvious, if a high-pressure situation develops while the block valve is closed, the system could overpressure and rupture. For this reason, other companies prohibit the use of block valves below relief valves altogether.

  If it is necessary to work on relief valves routinely, protection can be provided by installing two or more relief valves at each location. That way, one relief valve can be blocked in while the others provide protection.

  The following guidance can help minimize the risk associated with having block valves below relief valves.

  1. If a rupture disc is used between the block valve and the relief valve, the bleed valve should be installed between the block valve and the rupture disc.
  2. Full-port gate valves are the preferred type of block valve.
  3. Block valves should not be installed in any relief valve system of any boiler or steam generator constructed to the requirements of the ASME boiler and pressure vessel code, power boilers, section 1. Many state boiler laws also prohibit this practice.
  4. The block valves must be locked open when the relief valve is in service.
  5. The status of the block valves should be checked frequently.

     When a relief valve is removed for testing, the vessel that it was protecting no longer has that safeguard against overpressure. Ideally, the equipment item will be shut down and opened to the atmosphere. In many facilities block valves are installed immediately below the relief valve. The block valve is normally in the open position (either car-sealed or locked). When the relief valve has to be removed for maintenance, the block valve is closed so that the system can remain in operation. (If a gate valve is used, it should be installed horizontally so that, where the gate to fall off the stem, it would not inadvertently block the line).

Some facilities use dual relief valves tied in to a three-way valve so that at least one relief valve remains in service at all times.

During the time that the vessel is operating in this manner, it is necessary to have some other means of protecting the vessel from overpressure. One way of doing this is to have an operator stand by a block valve that can be opened so as to de-pressure the vessel to a vent or flare. If he receives instructions from the control room, or if he notices anything amiss, he will immediately open this valve. The block valve should not allow more than 3% pressure drop; quarter-turn valves (e.g., Plug or butterfly valve) should have a position indicator positively secured to the stem.

Whatever system is chosen, the pressure drop between the vessel and the relief valve is limited to 3% of the relief valve's set pressure.

Fail-safe control valves

Control valves on inlet, outlet, and reflux streams are crucial for overpressure protection during plant problems involving loss of utilities such as steam, electrical power, and instrument air. Normally, feed valves should fail closed; outlet and reflux valves should fail open. However, there are exceptions, and each situation must be individually evaluated during the PHA.

Shared relief valve

If two or more vessels share a single relief valve, there may be circumstances where one of the vessels has to be isolated from the relief system. In such cases, it is vital that a strict policy to do with locking valves in the correct position be followed.

If one relief valve protects two or more vessels, the following rules should be followed.

- The relief valve capacity must be adequate to protect both vessels for applicable scenarios. The set pressure must be at or below the MAWP of the vessel with the lowest design pressure. Pressure losses through the piping must be considered.
- There are no valves, check valves, or automatic control valves that may inadvertently isolate the vessels.
- The gate valves that isolate the vessels must be a horizontal stem, manually operated, and locked open.
- The combined wetted surface - below 10 meters - of all the vessels connected to the single safety valve is used in computing heat input from fire.

2.2.23 Repair techniques

The first consideration when planning a repair is understanding the root cause of the problem that led to the repair. On the basis of this understanding, a repair strategy is established, which addresses six key decisions; repair technique, materials (chemistry, mechanical properties, corrosion resistance), design (flow and system logic, sizing), fabrication (joining, welding, heat treatment), examination (NDE of the failed component and the repair), testing (hydro test, pneumatic test, leak test).

A repair plan is then developed and implemented. The repaired component remains in service for as long as its design life justifies it. In other words, no repair is temporary or permanent; instead, each repair will last as long as its weakest component. It is therefore essential, with each repair, to define a useful life (or design life) of the repair, and plan periodic inspections to confirm this useful life.

Replacement

The most common practice for repairing pipe sections or components is, of course, to replace them. The new component or sub assembly should fully comply with the construction code, preferably a recent edition of that code. In some cases, regulators or owners will impose the original code edition (the so-called code of record) for materials, design or fabrication of replacement components. This is seldom technically justified and is impractical.

An important consideration in planning the removal of the degraded section of pipe or component is to carefully and clearly specify lockout, tagout, depressurisation, draining and venting the pipe before cutting or opening the system.

Grinding out defects

When base metal or welds contain fabrication or service-induced defects (weld flaws, arc burns, gouges or cracks), these defects can be excavated by grinding, under certain conditions. The ground surface is then examined by liquid penetrate or magnetic particle to confirm that the defect has been removed. The ground out area may be left as is, without weld deposit, if the remaining wall thickness exceeds the minimum required by code, the ground profile is smooth (3:1 profile or smoother) and the remaining wall is sound.

Mechanical clamp

A mechanical clamp is a housing comprised of two half shells, with two end gasket rings that are tightened against the pipe outer diameter by bolting. Mechanical clamps are commonly used in power and process piping systems.

Certain clamps may be welded to the pipe, in which case the clamp may be pressure tested and the welds examined.

Mechanical clamps are also permitted for temporary repair of nuclear power plant class 2 and class 3 piping systems provided the clamp is designed assuming full severance of the pipe, and the area in the vicinity of the clamp is regularly inspected.

Composite overwrap

The use of a non-metallic composite overwrap is a repair technique for corroded or dented pipes or pipelines that does not require welding [fr-60]. Some composite over wraps follow the same principle as a type a full encirclement sleeve. Their objective is to reinforce the corroded wall thus avoiding outward bulging of the pipe wall that precedes burst failure of the thinned area.

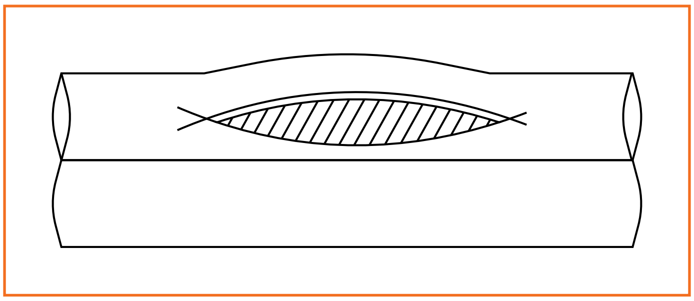

Fig: 2.2.6 Ductile Burst is Preceded by Outward Bulging

Other overwrap sleeves also provide a leak tight boundary: A resin impregnated fibre glass is wrapped by hand several times around the leaking pipe, and left to cure, figure 23-13. The cured wrap solidifies around the pipe and seals the leak.

Buried pipe rehabilitation

The HDPE liner is first deformed into a u-shape, and pulled through the existing pipe. Two important considerations for this repair technique are (1) the remote cut out and proper sealing of branch openings to avoid infiltration in the pipe-liner annulus, and (2) sealing the pipe-to-liner terminations.

The choice of the liner material is important because polymer liners can lose their function by collapse under annulus pressure by permeation or from chemical dissolution. Gas permeation becomes a concern when the line pressure drops and the annulus pressure becomes sufficient to collapse the liner. Poly amide liners.

The trench less repair of long runs of underground pipe can also be achieved by the insertion of a liner which unfolds inside-out as it is inserted, and then is heated and cured in-place (in-situ) to bond with the existing pipe. This repair technique is used in many applications, including waterworks and gas pipelines.

First, the liner is selected and designed to restore the strength of the deteriorated pipe. This design depends on the extent of degradation, established by wall thickness and condition inspections of the host pipe, and the properties of the liner.

The liner can be sized to provide, by itself, the full strength of the degraded host pipe. The host pipe is cleaned from debris and sharp protrusions that may damage the liner or prevent proper contact between the liner and host pipe.

The resin-saturated tube is introduced at a staging point at one end of the pipe. The liner is secured to the end of the pipe and inverted while being pushed into the degraded host pipe by hydrostatic pressure. Once fully inserted, with the resin now in contact with the host pipe inner diameter, the water in the liner is heated or steam is circulated, which causes the resin to cure and bond with the host pipe. The liner is subjected to a final visual inspection. Surface flaws may be corrected by grinding and trowel of newly mixed resin to fill the repaired area. Voids may be repaired by drilling small access holes through which newly mixed resin is injected. Samples of the cured resin are tested to confirm material properties used in design.

Brushed and sprayed lining and coating

A number of linings (covering the inner diameter) and coatings (covering the outer diameter) can be rolled, brushed or sprayed on the pipe to stop erosion, corrosion or abrasion of the pipe wall. Typically they are classified as thin (less than 20 to 40 mil paint types) or thick (over 40 mils). The pipe is cleaned by blasting or scraping to white metal with a smooth profile [SSPC]. The pipe may be rinsed with a solvent to clean dust particles and primed to avoid rust on the newly exposed surface. This cleaning step is critical to assure proper adhesion of the new lining to the existing pipe. The lining is then applied. It may consist of a sealer to prepare the surface by filling pits and surface defects and an epoxy based resin with a curing agent, and possibly mineral reinforcements. One or two applications may be necessary to achieve the required thickness.

Linings are factory applied on new pipes or applied in the field. With large diameter pipe, the lining is applied by field spray, brush or roll by a qualified operator wearing the necessary protection and breathing air mask, crawling inside the pipe. Where this is not possible, the operation can be performed by remotely controlled tools such as mechanical and chemical cleaning pigs followed by a crawler with rotating heads that spray the coating on the pipe, with remote camera inspection of the process. The access of crawlers may be limited by valves, tees or elbows.

If the degradation is due to aggressive abrasion of the inner diameter, a ceramic reinforced epoxy liner may be used. To protect against abrasion of the outer diameter, such as scratching on the surface of pipelines during directional drill insertions, an epoxy based polymer concrete may be used to protect fusion bonded epoxy or coal tar enamel coating. With the right hardener, the concrete-epoxy may be used directly on steel pipe. This concrete-epoxy coating is applied in thickness as low as 10 mils.

Pipe straightening

While it is preferable to replace an accidentally bent pipe, there are times where this may not be feasible. In these cases, an accidentally bent pipe may be straightened back into position, with certain precautions.

- The initial accidental bending and subsequent straightening should not cause a dent or gouge.
- The pipe cross section should not ovalise more than permitted in the construction code.
- The pipe cross section should not ovalise more than permitted in the construction code.
- Cold straightening (where the straightening operation takes place below the minimum transition temperature of the metal, for example 1300°F for carbon steel) is possible if permitted by the construction code, otherwise straightening should be performed at the hot bending temperature specified by the construction code. Flame straightening should be limited to 1200°F for plain carbon steel, 1000°F for specially heat-treated steel, and 700°F for stainless steel. The line may be forced into shape, restrained and then heated while restrained for stress relief. There strains can then be removed once the line is cooled to ambient temperature.
- In critical service, if the straightened pipe contains a weld joint, the weld should be volumetrically examined. The integrity of any mechanical joints (flange, tube fitting, etc.) Should be evaluated separately.

2.2.24 Control & monitoring instrumentation for oil & gas

Instrumentation is used to monitor and control the process plant in the oil, gas and petrochemical industries. Instrumentation comprises sensor elements, signal transmitters, controllers, indicators and alarms, actuated valves, logic circuits and operator interfaces.

An outline of key instrumentation is shown on process flow diagrams (PFD) which indicate the principal equipment and the flow of fluids in the plant. Piping and instrumentation diagrams (P&ID) provide details of all the equipment (vessels, pumps, etc), piping and instrumentation on the plant in a symbolic and diagrammatic form.

The elements of instrumentation

Instrumentation includes sensing devices to measure process parameters such as pressure, temperature, liquid level, flow, velocity, composition, density, weight; and mechanical and electrical parameters such as vibration, position, power, current and voltage.

The measured value of a parameter can be displayed and recorded either locally and/or in a control room. If the measured variable exceeds pre-defined limits an alarm may be provided to warn the operating personnel of a potential problem. Automatic executive action can also be taken by the instrumentation to close or open shut down valves and dampers, or to trip (stop) pumps and compressors.

Correct operation of the petrochemical process plant is achieved through the action of control loops. These automatically maintain and control the pressure, temperature, liquid level and flow rate of fluid in vessels and piping. Such control loops generally work by comparing the measured value of a parameter on the plant, e.g. Pressure, with a pre-determined set point. Any difference between the measured variable and the set point generates a signal which is used to modulate the position of a control valve (the final element) to maintain the measured variable at the set point.

Valves can be actuated by an electric motor, hydraulic fluid or air. For air-operated control valves, electrical signals from the control system are converted to an air pressure for the valve actuator in a current/ pneumatic i/p converter. Upon loss of pneumatic or hydraulic pressure valves can be configured to fail to an open (FO) or fail to a closed (FC) position.

Some instrumentation is self-actuating. For example, pressure regulators maintain a constant pre-set pressure, and rupture discs and pressure safety valves open at pre-set pressures.

Instrumentation includes facilities for operating personnel to intervene in the plant either locally or from a control room. Personnel can open or close valves, change set points, start and stop pumps or compressors, over-ride shut down functions (in specific controlled circumstances such as during start-up).

Temperature instrumentation

Measurement of temperature of fluids in the petrochemical industry is undertaken by temperature elements (TE). These can be thermocouples or platinum resistance temperature detectors (RTD's). The latter are used for their good temperature response. Local temperature indicators (TI) are located on the inlet and outlet streams of heat exchangers to monitor the performance of the heat exchanger.

In industrial applications gaseous or liquid fluids may need to be heated or cooled. This duty is undertaken in a heat exchanger, whereby the fluid is heated or cooled by heat transfer with a second fluid such as water, glycol, hot oil or another process fluid (the heating or cooling medium).

Temperature control is used to maintain the desired temperature of the first fluid. A temperature sensor transmitter (TT) is located in the first fluid at its outlet from the heat exchanger. This measured temperature is fed into the temperature controller (TIC) where it is compared to the desired set point temperature. The output of the controller, which is related to the difference between the measured variable and the set point, is fed to a control valve (TCV) in the second fluid to adjust the flow of the heating or cooling medium. In the case of a fluid being cooled, if the temperature of the fluid rises the temperature controller acts to open the TCV increasing the flow of the cooling medium which increases the heat transfer and reduces the temperature of the first fluid. Conversely if the temperature falls the controller acts to close the TCV which reduces the heat transfer increasing the temperature of the first fluid. In the case of heating medium with the falling temperature of the first fluid the controller would act to open the TCV to increase the flow of heating medium thereby raising the temperature of the first fluid. The controller (TIC) may also generate high (TAH) and low temperature (TAL) alarms to warn operating personnel of a potential problem.

Fin fan coolers use air to cool gases and liquids. The temperature of fluid is controlled (TIC) by opening or closing dampers on the cooler or adjusting the speed of the fan or the pitch angle of the fan blades thereby increasing or decreasing the flow of air.

Temperature monitoring and control instrumentation is used in fired heaters and furnaces to adjust the fuel flow valve (FCV) to maintain a desired thermal output. Waste heat recovery units (WHRU) are used to extract heat from the flow of hot exhaust gases from a gas turbine to heat a fluid (heating medium). Instrumentation includes controllers to maintain a desired temperature of the heating medium by closing or opening dampers in the exhaust gas flow.

Low temperature alarms (TSL) are used where cold fluids could be routed to pipework which is not suitable for cold service. Instrumentation may include an initial alarm (TAL) and then a shut down action (TSLL) to close a shut down valve (XV).

Temperature sensors (TE) are used to indicate that plant flares have been unintentionally extinguished (BAL), perhaps due to insufficient flow rate of gases to maintain a flame.

Pressure instrumentation

Many oil, gas and petrochemical processes are undertaken at specific pressures. Pressure is measured by pressure sensors (PE) which are arranged to transmit pressure (PT) signals to pressure controllers (PIC). Pressure vessels and tanks are also usually provided with local pressure indicators (PI).

Pressure in the petrochemical industry is frequently controlled by maintaining a constant pressure in the upper gas space of a vessel. The controller (PIC) adjusts the setting on a pressure control valve (PCV) that feeds gas forward to the next stage of the process. A rising pressure in the vessel results in the PCV opening to feed more gas forward. If the pressure continues to rise some controllers then act to open a second PCV that feeds excess gas to the flare system. The pressure transmitter is configured to provide warning alarms (PAL and PAH) if the pressure exceeds set high and low limits. If these limits are further exceeded (PALL and PAHH) an automatic shut down of the system is initiated which includes closure of the inlet valves of the vessel the pressure sensor (PT) that initiates a shut down is a separate instrument loop from the pt associated with the pressure control loop to mitigate common mode failures and to ensure greater reliability of the shut down function.

The operation of hydro cyclones is controlled by pressure instrumentation that maintains fixed differential pressures between the inlet and the oil and water outlets.

Turbo-expanders are controlled by maintaining the inlet pressure (PIC) at a constant value by controlling the angle of the expander inlet vanes. A split range pressure controller may also modulate a Joule Thomson valve across the turbo-expander.

Pressure in blanketed tanks is maintained by self-actuating pressure control valves (PCVs). As liquid is withdrawn from the tank the pressure in the gas space falls. The blanket gas supply valve opens to maintain the pressure. As the tank fills with liquid the pressure rises and a vent gas valve open to vent gas to atmosphere or a vent system.

Two important items of pressure instrumentation are rupture (bursting) discs (PSE) and pressure relief or pressure safety valves (PSV). Both are self-actuating and are designed to open at a pre set pressure to provide an essential safety function on the petrochemical plant.

Flow instrumentation

The throughput of a petrochemical plant is measured and controlled by flow instrumentation.

Flow measuring devices (FE) include vortex, positive displacement (PD), differential pressure (DP), coriolis, ultrasonic, and rota meters.

The flow through compressors is, at its simplest form, controlled by measuring the flow (FT) through the machine at the discharge and controlling the speed (FIC/SIC) of the prime mover (electric motor or gas turbine) that is driving the compressor. Anti-surge control ensures a minimum flow of fluid through the compressor. This requires measurement of flow (FT) at the discharge plus measurements of the suction and discharge pressures (PT) and temperatures (TT) of the fluid flowing through the compressor. The anti-surge controller (FIC) modulates a control valve (FCV) which recycles cooled gas from downstream of the compressor after-cooler back to the suction of the compressor. Low flow alarms (FAL) provide a warning indication to operating personnel.

Large process pumps are provided with minimum flow protection. This comprises measurement of flow (FT) at the pump discharge, this measurement is an input to a flow controller (FIC) whose set point is the minimum flow required through the pump. As the flow reduces to the minimum flow value the controller acts to open a flow control valve (FCV) to recycle fluid from the discharge back to the suction of the pump.

Flow metering (FIQ) is required where custody transfer of fluids takes place, such as an outgoing pipeline or at a tanker loading station. This requires accurate measurement of the flow with inputs such as liquid density.

Flare and vent systems need to be purged to prevent air ingress and the formation of potentially explosive mixtures. The flow rate of purge gas is set by rota meter (FIC) or fixed orifice plate (FO). A low flow alarm (FAL) provides a warning indication to operating personnel that the purge flow has reduced significantly.

Pipelines are monitored by measuring the flow rate of fluid at each end, a discrepancy (FDA) may indicate a leak in the pipeline.

Level instrumentation

The level measurement of liquids in pressure vessels and tanks in the petrochemical industry is undertaken by differential pressure level meters, radar, magnetostrictive, nucleonic, magnetic float and pneumatic bubbler instruments.

Level instrumentation determines the height of liquids by measuring the position of a gas/liquid or liquid/liquid interface within the vessel or tank. Such interfaces include oil/gas, oil/water, condensate/water, glycol/condensate, etc. Local indication (LI) includes sight glasses which show the liquid level directly through a vertical glass tube attached to the vessel/tank.

Phase interfaces are maintained at a constant level by level transmitters (LT) transmitting a signal to a level controller (LIC) which compares the measured value with the desired set point. The difference is sent as a signal to a level control valve (LCV) on the liquid outlet from the vessel. As the level rises the controller acts to open the valve to draw off liquid to reduce the level. Similarly as the levels fall the controller acts to close the LCV to reduce outflow of fluid.

High and low level alarms (LAH and LAL) warm operating personnel that levels have gone outside predefined limits. Further deviation (LAHH and LALL) initiates a shut down either to close emergency shut down valves (ESDV) on the inlet to the vessel or on the liquid outlet lines. As with high and low pressure instrumentation the shut down function should comprise an independent measurement loop to prevent a common mode failure. Loss of liquid level in the vessel may lead to gas blow by where high pressure gas flows to the downstream vessel through the liquid outlet line. The integrity of the downstream vessel may thereby be compromised. In addition high liquid level in the vessel may lead to carry over of liquid into the gas outlet which could damage downstream equipment such as gas compressors.

Analyser instrumentation

A wide range of analysis instruments are used in the oil, gas and petrochemical industries.

- **Chromatography:** To measure the quality of product or reactants.
- **Density (oil):** For custody metering of liquids.
- **Dew point (water dew point and hydrocarbon dew point):** To check the efficiency of dehydration or dew point control plant.
- **Electrical conductivity:** To measure the effectiveness of potable water reverse osmosis plant.
- **Oil-in-water:** Prior to discharge of water into the environment pH of reactants and products.
- **Sulphur content:** To check the efficiency of gas sweetening plant.

Other instrumentation

Major pumps and compressors may be provided with vibration sensors (VT) to provide operating personnel with a warning (VA) of potential mechanical problems with the machine.

Rupture discs (PSE) and pressure safety valves (PSV) are self-actuated and provide no immediate indication that they have ruptured or lifted. Instrumentation such as pressure alarms (PXA) or movement alarms (PZA) may be fitted to indicate that they have operated.

Corrosion coupons and corrosion probes provide a local indication of corrosion rates of fluids flowing in piping.

Pipeline pig launchers and receivers are provided with a pig signaller (XI) to indicate that a pig has been launched or has arrived.

Packaged items of equipment (compressors, diesel engines, electricity generators, etc) will be provided with local vendor supplied instrumentation. If the equipment malfunctions a multi variable signal (UA) may be sent to the control room.

The fire and gas detection system comprises local sensors to detect the presence of gas, smoke or fire. These provide alarms in the control room. Simultaneous detection of multiple sensors initiates action to start fire water pumps and close fire dampers in enclosed spaces.

The petrochemical plant may have several levels of shut down. A unit shut down (USD) entails shut down of one limited unit with the rest of the plant remaining in operation. A production shut down (PSD) entails shut down of the entire process plant. An emergency shut down (ESD) entails complete shut down of the plant.

Summary

- Crude oil is a naturally occurring, unrefined petroleum product and can be refined to produce usable products such as gasoline, diesel, and various other forms.
- Crude oil is formed from the remains of dead organisms that existed millions of years ago in a marine environment.
- After the extraction of crude oil from the ground, it must be transported and refined into petroleum products that have some value.
- The basic functions of the refinery have three chemical processes distillation, crackling, reforming.
- Natural gas moves from natural gas and oil wells through a gathering system of pipelines to natural gas processing plants for treatment.
- The basic stages of natural gas processing/treatment are, gas-oil-water separators, condensate separator, dehydration, contaminant removal, nitrogen extraction, methane separation, fractionation.
- Flow lines move crude oil or natural gas from producing wells to producing field storage tanks and reservoirs.
- Gathering lines collect oil and gas from several locations for delivery to central accumulating points.
- Natural gas and crude oil are moved long distances from producing areas to refineries and from refineries to storage and distribution facilities by 1- to 3-more larger-diameter trunk pipelines.
- Petroleum product trunk pipelines move liquid petroleum products such as gasoline and fuel oil from refineries to terminals, and from marine and pipeline terminals to distribution terminals.
- Product pipelines are used to move LPG from refineries to distributor storage facilities or large

industrial users.

- Hot work permit is issued for work which involves the application of heat or sources of ignition to vessels or equipment which may contain or have contained flammable vapour.
- Cold work permit is issued for work involving hazardous activities which are not covered by a hot work permit.
- Electrical work permit is used when working on a piece of equipment or a circuit that is safe.
- Confined spaces entry certificate are used when entry to a confined space is essential for work to be done.
- Pressure vessels are leak-proof containers that store liquid or gas.
- Reflux vessels feed cool liquid to columns and vessels.
- Pumps are at the heart of all process facilities. They are also a source of hazards because they have moving parts and a seal between their contents and the atmosphere.
- There are different types of heat exchangers, shell and tube heat exchangers, air-cooled exchangers
- Fired heaters transfer are used when the process material has to be heated to a high temperature.
- Internal combustion engines have many applications in both stationary and mobile equipment, large stationary engines, mobile engines fuelled by gasoline, diesel, or LPG are some of its types, cooling towers, etc.
- Blinds, also known as blanks or spades, blinds provide positive isolation between sections of a process.
- Valves are used to stop and/or control the flow of fluid in piping systems. The different types of valves are block valves, self-closing valves, check valves, emergency isolation valves, excess flow valves.
- The lighting of fired heaters always has the potential to create an explosion.
- In case of pipe class changes, it is important to make sure that the lower grade of steel is not located too near the more severe service.
- Hydraulic hammer is created by stopping and/or starting a liquid flow suddenly.
- When base metal or welds contain fabrication or service-induced defects (weld flaws, arc burns, gouges or cracks), these defects can be excavated by grinding, under certain conditions.
- A mechanical clamp is a housing comprised of two half shells, with two end gasket rings that are tightened against the pipe outer diameter by bolting.

Exercise

1. **It is a document which sets out the work to be done, precautions to be taken for all foreseeable hazards.**
   a) Request to proposal b) Invoice
   c) Work Permit System d) Work Order

2. **This type of permit is used when working on a piece of equipment or a circuit that is safe.**
   a) Hot work permit b) Cold work permit
   c) Electrical work permit d) Confined spaces work permit

3. **These are the leakproof containers that stores liquid and gas.**
   a) Reflux vessels b) Pressure vessels
   c) Volume vessels d) Storage vessels

4. **These valves are used to totally stop the flow of liquid or gas through a pipe.**
   a) Self-Closing Valves b) Block valves
   c) Excess flow Valve d) Check valves

5. **These are used where failure to close a valve manually might permit flow of oil or gas into areas where a serious fire may result.**
   a) Self-Closing Valves b) Block valves
   c) Excess flow Valve d) Check valves

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Pipeline leak repair clamps

3. Carry out repair, maintenance and testing of equipment in oil and gas pipeline

Unit 3.1 - Carry out repair and preventive maintenance

Unit 3.2 - Testing of equipment & machine after repair

HYC/N6403

Key Learning Outcomes

At the end of this module, the participant will be able to:

1. Carry out repair and preventive maintenance
2. Isolate or remove the damaged part/equipment
3. Check reassembled equipment/machine
4. Monitor activity in and around pipeline and operation facilities
5. Testing of equipment & machines after repair
6. Perform 5S activities post repair and maintenance
7. Prepare the repair and maintenance report

Unit 3.1 - Carry out repair and preventive maintenance

Unit Objectives

At the end of this unit, the participant will be able to:

1. Carry out repair and preventive maintenance
2. Isolate or remove the damaged part/equipment
3. Check reassembled equipment/machine

3.1.1 Introduction

The term maintenance refers to repairing equipment that has failed or taking corrective action before the item actually does fail.

Types of maintenance

Maintenance work falls into one of the following four categories.

- **Repair:** The most common type of maintenance is the repair of an item which has failed or which is showing imminent signs of failure. This type of maintenance tends also to be the most hazardous because there may not be much time to plan the job, and the repair work may be going on while the rest of the facility is in operation. In addition, the maintenance workers may be under pressure to get the work done quickly in order to avoid a larger system shut down. Such pressure may lead to short cuts being taken.
- **Condition-based maintenance:** Condition-based maintenance is carried out when an equipment item starts to show early signs of failure or when its performance becomes degraded.

  For example, if the discharge pressure of a pump starts to fall the pump may be taken out of service and repaired before it fails.

  Condition-based maintenance tends to be less hazardous than repair maintenance because it can be properly planned, and it can be carried out without the workers feeling that they are in a rush. Ideally, condition-based maintenance will be carried out while the unit is shut down, thus making conditions even safer for the maintenance workers.

  Examples of monitoring activities that could lead to the need for condition-based maintenance include the following:

  - Process performance.
  - Vibration analysis.
  - Oil analysis.
  - Thermography.
  - **Scheduled maintenance:** some equipment and instrument items are serviced on a scheduled basis, regardless of the actual performance or condition of those items. A common example

of this type of maintenance is the routine replacement of lubricating and seal oils.

Example of an instrument loop maintenance schedule:

Item	Months
High integrity protection loops	6
Shut down and alarms system (SILP2)	6
Shut down and alarm system (SILP1)	12
Control and monitoring system	24
Non safety alarms	24
Indicator	24
Ancillary instruments	36

Table: 3.1.1 Instrument loop maintenance schedule

- **Reliability-centred maintenance (RCM):** Reliability-centred maintenance (RCM) uses a risk-based approach to organizing maintenance activities. Those items that contribute the most to overall risk receive a higher maintenance priority than those that are considered to be less critical.

An RCM analysis is typically built around the following steps:

A component list is developed for the section of the facility that is being analysed.

- A failure analysis, possibly using the failure modes & effects analysis (FMEA) method, is carried out for each component.
- A criticality is assigned to each failure mode.
- A scheduled maintenance program that focuses on the high criticality items is set up. This program can be condition-based.

The RCM program should include a process for analysing equipment failures and applying the lessons learned from those analyses such that overall risk can be reduced. The analysis can also help determine the required inventory for spare parts.

3.1.2 Maintenance task organization

The organization of a maintenance task can be divided into the following eight steps.

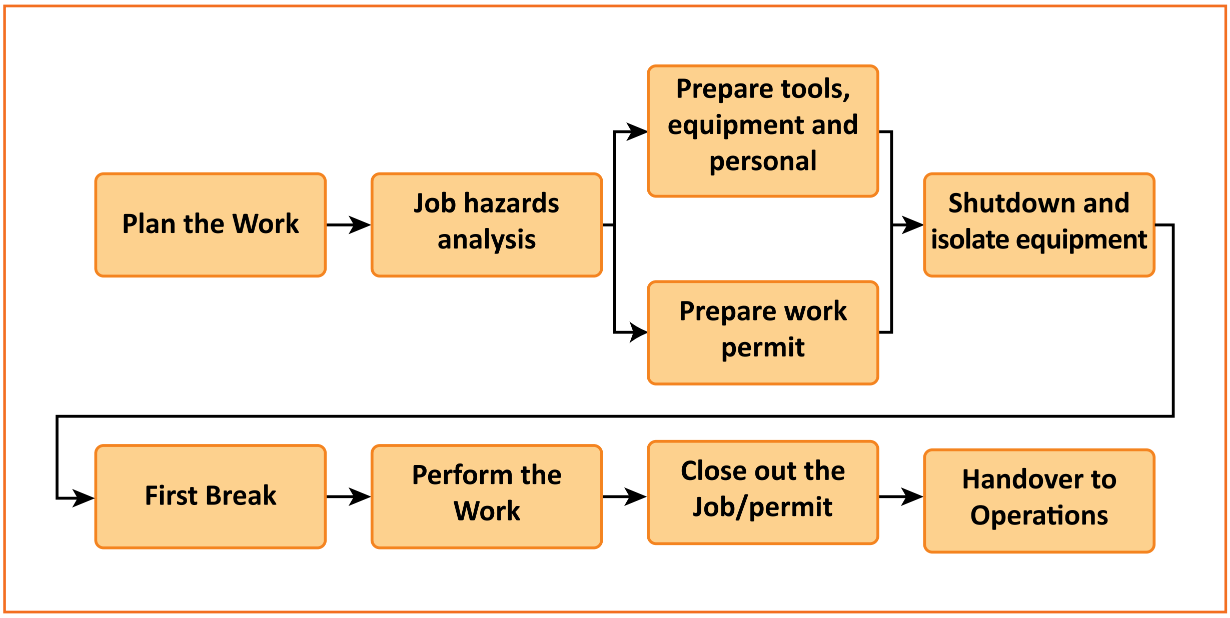

Fig: 3.1.1 Ductile Burst is Preceded by Outward Bulging

Step 1: Plan the work

The first step is to determine what the task is and how it is to be done. This step also means identifying and listing the affected pieces of equipment and determining what impact the maintenance work is likely to have on the overall operation. For a large, continuously operating unit, an important part of the plan is to determine what other parts of the facility will have to be shut down and to determine how those items that are to be left running are to operate during this particular maintenance task. Therefore, an isolation plan is required.

It is very important at this stage to determine if the work is truly routine maintenance, or if it falls under the scope of the MOC program.

Before maintenance work starts it is important to check that the following activities have been carried out:

All equipment is either on site or scheduled for delivery (components should be assembled in an area adjacent to where the work is taking place).

- Piping is fabricated in advance.
- Everything is field verified, and measurements are checked.
- As-built drawings are updated or verified.
- The path of travel for each piece of installed equipment is identified, as well as for any heavy construction equipment needed.
- Construction materials are placed in convenient locations and safety gear and special equipment are prepositioned in pre-packaged kits near the work area.
- Spare parts and consumable supplies are fully stocked.
- The turnover/start-up plan has been reviewed by all affected parties.

The job plan should include the following items:

- Equipment description.
- Location of the work.
- Work description.
- Time needed for the work.
- Name of person(s) requesting the work.
- MOC clearance - if needed.
- Sources of high energy normally present.
- Isolation points.
- Lock/tag applications at each isolation point.
- Shut down procedures.
- Methods for removing stored/residual energy.
- Tools and equipment needed for the work.
- First break procedures.
- Identification of all personal tags and locks.
- Sign-off procedures for job completion.
- Sign-off procedures for putting equipment back in service.

Step 2: Conduct a JHA

For all but the simplest jobs a JHA or job safety analysis (JSA) should be carried out before a permit to work is issued. The analysis consists of the following steps.

- Analyse each task in order to identify the associated hazards.
- Assess the consequence, likelihood, and risk of each of the identified hazards using a risk matrix.
- Ensure that sufficient precautions (safeguards) have been put in place to place the risk in an acceptable range.

Depending on the nature of the task to be analysed, a JHA can be conducted at the following one of three levels:

- For simple, low-risk jobs that have been carried out before, a pre-job discussion and tailgate/toolbox talk will generally be sufficient.
- For more complex tasks, permit discussions and a review of the precautions required in the permit should be carried out.
- For more complex and risky tasks (which always include any kind of equipment entry or line break), a full hazards analysis should be performed.

Step 3: Issue a work permit

Once the job scope has been defined and a hazards analysis performed, a work permit is issued by the operations department. The permit will include all information needed to ensure that the maintenance work is carried out safely. In order to save time, the tools, equipment, replacement parts, and personal protective equipment (PPE) that will be needed can be assembled in parallel with the permitting steps.

Step 4: shut down and isolate equipment

The next step is to determine how the affected unit(s) are to be shut down. The shut down procedure may be included in the standard operating procedures. However, in many cases, maintenance work involves carrying out unusual or non standard tasks. In such cases, temporary operating procedures will be needed, particularly if it is intended to keep the facility operating while the maintenance work is being carried out. Issues to watch for include the following:

- Sudden changes in utilities consumption.
- Inventories of intermediate chemicals.
- Changes in flow rates.

Once the equipment is shut down, it can be isolated, vented, and drained.

Step 5: First break

The workers can then carry out the **"first break,"** i.e., They open the first flange or electrical connection. It is when the workers are actually exposed to the system for the first time. This is a potentially dangerous time because, if the preparations have not been carried out properly, there may be an unexpected release of hazardous materials. Therefore, it is normal for extra precautions, such as the use of more PPE, to be undertaken at this time.

When separating the flanges of a line, consideration should be given to installing a grounding lead, which should be installed across the sections of pipe to be parted to protect against stray currents generating a spark when parting the line. Stray currents could be generated by energy sources that have not been properly de-energised, such as cathodic protection of the pipe system or nearby equipment.

The discussion to do with installing blinds provided later in this chapter also provides guidance to do with breaking flanges.

Step 6: perform the work

Once the first break has occurred, and assuming that everything is in order, the workers can carry out the maintenance task.

Step 7: Close out the work/permit

It is important to be vigilant during the restart process because there is often a temptation to skip steps in order to get the unit back into full operation as quickly as possible.

When the work is complete all copies of the permit should be returned to the issuing point. The permit-issuer should then inspect the work site to confirm that the work has been completed as intended and that the work site has been left in a safe and tidy condition, that all blinds have been removed, and that there are no other open permits that apply to the same equipment. Only then should the permit-issuer sign off the permit.

Closing out the permit does not necessarily mean that the equipment is ready to start up. In particular,

a tightness pressure test must be performed. A housekeeping check should also be carried out, with particular focus on the following:

- All trash has been removed.
- All unused materials have been removed.
- All scaffolding has been dismantled.
- The site has been washed down.
- Unused parts have been returned to the store.
- The site is in a clean, tidy, and safe condition.

Step 8: Handover to operations

Once the maintenance work is complete, the equipment and instrumentation are handed over to operations.

Readiness review

An operational readiness/pre start-up safety review may be needed, particularly if the design of the system was changed in any way or if process conditions will change following the maintenance work. For large maintenance tasks, a turnover package may be required. (Information on these topics is provided in process risk and reliability management.)

It is important that the maintenance team report on what they observed and the actions that they took, along with suggestions as to how the equipment or system can be improved. This information provides management with insights as to how equipment and systems can be improved so as to reduce the number of future breakdowns and reduce maintenance costs.

Mechanical completion

Before a facility or piece of equipment is handed over to operations from maintenance, it should meet the following criteria before being considered as being mechanically complete.

Physically complete and clean

All piping, vessels, heat exchangers, and other equipment should have been flushed, cleaned, and dried. Equipment should be inspected to ensure that new welds are complete, all valves are closed with plugs installed, blinds of adequate thickness are installed, and all supports are in place.

Any new equipment should have been manufactured, fabricated, installed, and connected in accordance with the scope of work, the specifications and the design drawings. Temporary equipment needed for commissioning and start-up should be installed.

Tight

The system should be pressure tested. There should be no loss of pressure or leakage from equipment, piping, and joints during hydrostatic/pneumatic testing.

Inspected, tested, and documented

Inspections (both shop and field) should cover the following items.

- Bench calibration of instruments.
- Electrical insulation tests.
- Non-destructive testing (NDT) and pressure testing of piping.
- Integrity testing of valves.
- Structural fabrication and welding.
- Equipment alignment.
- Painting

3.1.3 Pressure tests

After a piece of equipment or piping that operates under pressure has been opened and then reassembled (**"buttoned up"**) it must be pressure tested before being put back into service.

There are two types of pressure test. The first is a tightness test, used after the equipment has been opened but not modified in any way. Typically this type of test is conducted after the item was opened for cleaning, inspection, or routine maintenance. The test ensures that the equipment is leak-free but it does not test the integrity of the vessel or piping itself. Tightness tests are never conducted at a pressure above the equipment or system design pressure or the relief valve set pressure.

The test pressure is generally 1.5 Times the design pressure or MAWP. Therefore, once a vessel has been installed, or anytime it is opened (say for inspection), it will be tested to that pressure before the process fluids are introduced into the vessel.

The second type of pressure test is a strength or hydro test. It is used when the equipment has been modified, say by having some welding done on it, or when structural repairs have been made. Strength test pressures are generally above the equipment or system normal design pressures or relief valve set pressure.

Regardless of the type of test being carried out, it is important first to visually inspect the equipment and to carry out the actions discussed above to do with mechanical completion.

Maximum allowable working pressure

- Pressure vessels must always operate at a pressure lower than their maximum allowable working pressure (MAWP). The manner in which MAWP is determined can be illustrated using pressure vessel V-101 in the second standard example.
- In the initial design, the process engineer specifies that V-101 be designed for a maximum operating pressure of 6.5 BARG. This is the design pressure or pressure rating of the vessel as measured at the top of the vessel.
- The process engineer's requirements are transmitted to the vessel engineer who designs the vessel using standard sizes for wall thickness and flange size, thus generating the MAWP value. Generally, MAWP will be higher than the design pressure because wall thicknesses are in discrete sizes and the designer.

- Once in service, the vessel can be operated at any pressure up to MAWP without violating any safety limits. However, if the operating pressure does ever go over MAWP for any reason, the vessel should be checked and re-certified. Management or supervision can never operate at a pressure exceeding MAWP without going through the MOC process.
- Generally emergency systems such as interlocks and pressure relief valves will be set at a value just below MAWP. If the internal pressure in a vessel continues to rise, then the walls will probably start to yield and around 2 times the MAWP. The vessel or associated piping may be slightly distorted, but any leaks are most likely to occur at gaskets. At this pressure it is likely that the vessel itself will not rupture.
- At 2 - 4 times the MAWP, there will probably be distortion of the vessel and it can be assumed that gaskets will blow out. The vessel's burst pressure will typically be in the range of 3.5 - 4 Times the MAWP. Therefore, for this example, the burst pressure would be in the 27 - 34 BARG range. (It is difficult to predict this value accurately because so few vessels actually fail, so there is not much field data.)

Increased temperatures quickly reduce the strength of the steel. For example, the MAWP for a certain vessel may be 10 BARG at a temperature of 300 °C. At 550°C the same item may fail at just 1 BARG (metal temperature refers to the average metal temperature through its entire depth). Therefore, each MAWP value must have an associated temperature.

Although low temperatures generally enhance metal strength (and so raise MAWP), very low temperatures may cause sudden and catastrophic embrittlement. This can be a serious problem in cryogenic services. For example, carbon steel equipment and pipe is liable to fail - even when there is no load on it - if its temperature falls below 220 °c. This can occur, e.g., If a cryogenic liquid such as liquid air enters a carbon steel flare header.

Test medium

The test medium can be either liquid (hydrostatic) or gas (pneumatic). Of the two liquid is strongly preferred, particularly for strength or hydrostatic tests. (Gas may be preferred for routine tightness tests since it is much simpler to use and there are fewer disposal problems once the test is complete.) The potential energy of a compressed gas is much greater than that for a non compressible liquid. Hence, if the item were to fail, it could disintegrate violently. Pneumatic testing should only be used when hydrostatic testing is impractical - e.g., When testing a vacuum system that does not have the physical strength to support the piping when full of liquid.

Water is normally used as the test medium unless it could cause problems such as corrosion. The test water should be clean and should be of such quality as to minimize corrosion of the materials in the test system. If the equipment being tested is made of stainless steel, the chloride content of the water should not exceed 30 ppm. If water is not used, then the liquid selected must be a temperature below its boiling point. The use of combustible liquids should be avoided.

When liquid is used, the effect of its weight on equipment (particularly the bottom heads of large, tall vessels), their supports, and foundations must be carefully evaluated. One chemical plant, e.g., Had large (72 inch) overhead lines coming from its vacuum columns. Because the normal operating pressure in those.

Columns was very low, the wall thicknesses were correspondingly low and the structural supports were minimal. Had liquid been introduced into these overhead lines, they and the supporting structure would have collapsed - hence testing had to be carried out with high pressure gas.

3.1.4 Tightness tests

As discussed above, tightness test pressures should not exceed the equipment MAWP or system design pressure or the vessel's relief valve set pressure. Once the system is at test pressure, it is held at that pressure for 15 - 20 minutes (1 hour maximum). If the pressure does not fall, then the system is tight. If the pressure does fall, then the leak must be found and repaired. Testing can be done using a soap solution if gas is being used as the testing medium. The solution is squirted on to the flanges that were parted and then put back together. Any gas leak will create bubbles in the solution.

3.1.5 Strength tests

Non-destructive methods to determine thickness loss, which should be performed before conducting a strength pressure test.

If the vessel or piping has been modified in any way, then a strength test is required in order to ensure the vessel's integrity. Strength tests are conducted above the vessel's design pressure and above the set points of associated relief valves/rupture disks (which are either removed, blocked in, or have their valve disk clamped).

A strength test must be conducted in accordance with the applicable codes and/or standards for which the equipment is constructed.

Vessels can be strength tested before being installed. However, piping is usually tested in the field. When testing a piping system attached to a pressure vessel, and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together.

3.1.6 Testing procedures

The following points must be considered when establishing a pressure testing procedure (whether it be a tightness or strength test). The procedures to be followed will differ somewhat depending on whether the test medium is liquid or gas.

- **Inspection:** Inspection is a crucial part of any operating and maintenance system. It is vital that equipment and instrument items that could fail - particularly where that failure could lead to a safety or environmental violation - are monitored, and that corrective action is taken before problems arise.

Inspection programs for all types of equipment should include the following elements:

1. Inspections to monitor the physical conditions of the vessels and columns and the type, rate and cause of corrosion, erosion, hydrogen blistering, stress cracking, or other deterioration.
2. The use of internal corrosion coupons and gauge points installed as checkpoints for the inspector.
3. The judicious use of corrosion inhibitors (when used at incorrect rates they can actually accelerate corrosion rates).
4. Records of corrosion rates, mechanisms of corrosion, locations of corrosion, and inhibitors used.
5. Information to do with equipment failures, maintenance, and repair methods.
6. Inspection and maintenance records of the pressure relief valves and other pressure-relieving devices.
7. Inspection of fireproofing systems.

Any small increase in wall thickness can be assumed to be attributable to measurement error. However, if the thickness continues to grow, or if a single measurement shows an unusually large increase (say more than 5% of a previous reading), then additional tests should be carried out.

- **Inspection records**

  The following minimum inspection records should be maintained.

  1. Date of inspection/test.
  2. Name of inspector/tester.
  3. Serial number of equipment.
  4. Description of test.
  5. Results of test.

- **Risk-based inspection:** A risk-based approach to inspection helps ensure that resources are allocated as effectively as possible. RBI can be used for all kinds of equipment, including tanks, pumps, compressors, and pressure vessels. RBI is particularly helpful when planning a scheduled turnaround, where there is usually limited time, and managers must decide which items to inspect first.

  Some of the discussion in the previous section to do with RCM that was provided above can also be applied to RBI programs.

  RBI programs typically are divided into the following three parts:

  1. **Analyse risk:** The first step is to define and quantify the risk of process equipment failure (safety, environmental, and economic). The risk analysis should include both the likelihood of failure of an equipment item and the consequences of such a failure. The analysis must consider all failure modes that could reasonably be expected to affect the piece of equipment in the particular service.

     The evaluation of consequence should consider, as a minimum process fluid properties and operating conditions, and flammability, explosive, toxic, and environmental effects.

The evaluation of likelihood should consider the following, as a minimum:

- All forms of degradation that could reasonably be expected to affect a vessel in any particular service. Examples of degradation mechanisms include internal or external corrosion or erosion, all forms of cracking (both internal and external), fatigue, embrittlement, creep, high temperature, and hydrogen attack.
- The effectiveness of the inspection practices, tools, and techniques utilized for finding the expected and potential damage mechanisms.
- The materials of construction.
- The equipment design and operating conditions.
- Appropriateness of the design standards and codes used.
- The effectiveness of corrosion monitoring and control programs.
- Quality of maintenance and inspection activities and programs.
- Equipment failure history and data.

Information to do with risk can come from process hazards analyses.

Spare parts

Well before commissioning starts, a sufficient supply of spare parts should be provided. Issues to consider include the following.

- The numbering system.
- The need for maintenance training to do with installing the spare parts.
- Storage requirements.
- Inspection of spare parts.
- Inventory control procedures.

2. **Determine the cost of equipment failures:** The next step is to analyse the cost of such failures in terms of safety, environmental violations, and overall business interruption, and determine what resources can be justified to reduce such failures.
3. **Allocate inspection resources:** The final step is to allocate inspection resources to those equipment items which pose the highest risk to the facility.

Exercise

1. **Which one of the following is not a type of maintenance?**
   a) Repair b) Rework
   c) Condition-based maintenance d) Reliability-centred
2. **This type of maintenance uses a risk-based approach to organizing maintenance activities.**
   a) Repair-monitored maintenance b) Condition-based maintenance
   c) Reliability-centred maintenance d) None of the above
3. **3. Which one of the following is a test which is conducted after the item was opened for cleaning, inspection, or routine maintenance.**
   a) Tightness Tests b) Pressure tests
   c) Strength Tests d) Hydro Tests
4. **A .... to inspection helps ensure that resources are allocated as effectively as possible.**
   a) Analysis- based approach b) Risk-based approach
   c) Inspection-based approach d) Result-based approach

Notes

Unit 3.2 - Testing of equipment & machine after repair

Unit Objectives

At the end of this unit, the participant will be able to:

1. Monitor activity in and around pipeline and operation facilities
2. Testing of equipment & machines after repair
3. Perform 5S activities post repair and maintenance
4. Prepare the repair and maintenance report

3.2.1 What is 5s?

First used by Toyota in the late 1960s, the 5-s system is defined as a method of workplace organization based on five Japanese words; **"seiri, seiton, seiso, seiketsu and shitsuke"**. These words roughly translate as **"sort," "orderliness," "cleanliness," "standardize"** and **"sustain."** Typically implemented as part of a lean initiative, 5-s is most effective when the entire organization adopts its principles, making it part of the business philosophy and an integrated part of the company culture.

The principles of 5S create an effective visual aspect; when everything is organized and clean, problems and hazards are more easily identified. For example, having a clean plant floor helps identify any leaks occurring from nearby machinery that otherwise would have gone unnoticed. Organization can reduce wasted time and motion by having tools and other materials in the right place, a seemingly small detail but something that adds up over time.

Breaking down the 5-s system

The 5-s system might be the least discussed and used **"lean"** technique, but it's a fairly straightforward process with significant benefits. It increases employee involvement, teamwork, safety and morale; reduces overall variability and uncertainty, which leads to a reduction in cost; and sets a good foundation for other lean principles.

Seiri (sort)

The necessary and unnecessary materials available in the workplace should be sorted and classified. Through the suitable sorting it can be identified the materials, tools, equipment and necessary information for realization the tasks. Sort by the tools that are frequently used are placed within easy reach, and those that are not used often. This leads to fewer hazards and less clutter to interfere with productive work.

- **On the first stage one should answer to so-called control questions:**
  1. Are unnecessary things causing the mess in the workplace?
  2. Are unnecessary remainders of materials thrown anywhere in the workplace?
  3. Do tools or remainders of materials to production lie on the floor (in the workplace)?
  4. Are all necessary things sorted, classified, described and possess the own place?

5. Are all measuring tools properly classified and kept?

If on any question answer is yes, it should execute sorting of things, which are in the workplace.

- On the second stage one should execute the review of all things which are in the workplace and group them according to the definite system. According to carried out sorting it should execute the elimination from the workplace the things, which were found **"unnecessary"**.
- To permanent usage the 1S rule is so-called the programmed of the red label. It means giving the red label to things, which operator will recognize as useless.

Benefit:

- Process improvement by costs reduction,
- Stock decreasing,
- Better usage of the working area,
- Prevention of losing tools,

Seiton (orderliness)

This means preparing the necessary items neatly and systematically so that they can easily be taken and returned in the original place after use. Forming a regular workplace, avoiding time loss while searching for material and so improving the efficiency are the main objectives. The goal is to minimize the number of moves that a worker has to perform during operation. Especially important is visualization of the workplace e.g. Painting the floor helps to identify the places of storage of each material or transport ways, drawing out the shapes of tools makes possible the quick putting aside them on the constant places, colouring labels permit to identify the material, spare parts or documents. Tools, equipment, and materials must be systematically arranged for the easiest and the most efficient access. There must be a place for everything, and everything must be in its place. Implementing the 2S rule.

It should execute the segregation of things and mark the places of their storing. Used things should always be divided on these, which should be:

- In close access (1st degree sphere),
- Accessible (2nd degree sphere),
- In the range of hand (3rd degree sphere).

O the estimation of the workplace in terms of the 2S rule that is setting in order things serve the following control questions:

- Is position (location) of the main passages and places of storing clearly marked?
- Are tools segregated on these to regular uses and on specialist tools?
- Are all transport palettes stored on the proper heights?
- Is anything kept in the area of devices against the fire?
- Has the floor any irregularity, cracks or causes other difficulties for the operator's movement?

Things used occasionally and seldom should be on the workplace but outside the direct using sphere. Their distance and location from the place of work should depend on the frequency of using these materials or tools. Places of storage should be marked in the manner making possible their quick identification. It can be used coloured lines, signs or tool boards.

Benefit:

- Process improvement (increasing of effectiveness and efficiency),
- Shortening of the time of seeking necessary things,
- Safety improvement,

Seiso (cleanliness)

In order to realize effective tasks, it is essential to create a clean and regular working and living environment. This is because dust, dirt and wastes are the source of untidiness, indiscipline, inefficiency, faulty production and work accidents.

Implementing the 3S rule:

The first step of realization the 3S rule is renovation the workplace. It is assumed that **"the first cleaning"** forces the exact checking of usage two of the previous rules. The usage of the 3S rule relies on everyday keeping in faultless cleanness the workplace. It is executed by the operator of the given workplace.

- Are the oil's stains, dust or remains of metal found around the position, machine, on the floor?
- Is machine clean?
- Are lines, pipes etc. Clean, will they demand repairing?
- Are pipe outlets of oils not clogged by some dirt?
- Are sources of light clean?

Benefits:

- Increasing of machines efficiency,
- Maintenance the cleanness of devices,
- Efficiency,
- Keep the clean workplace, easy to check,
- Quick informing about damages (potential sources of damages),
- Improvement of the work environment, elimination of the accidents‟ reasons,

Seiketsu (standardize)

To establish standards of the best practice in the workplace and to ensure that the standards are compiled and to undertaking that the workplace is clean and tidy at all times. The necessary systems are formed in order to maintain the continuance of these good practices at the workplace. Worked out and implemented standards in the form of procedures and instructions permit to keep the order on the workplaces. Standards should be very communicative, clear and easy to understand. Basic housekeeping standards apply everywhere in the facility. Everyone knows exactly what the responsibilities are. Housekeeping duties are part of regular work routines. There is a need after some period to choose the best ways to practice sort, set in order and cleaning and abide by them. To implementing 4S rules (seiketsu).

To maintain high standard of housekeeping.

- Is attention given to keep workplace neat and clean?
- Is workplace tidy but not completely clean?

Benefits:

- Safety increasing and reduction of the industry pollution.
- Working out the procedures defining the course of processes.

Shitsuke (sustain)

Once the first 4 principles are established it's now time to make them part of your organization's standard routine. Seiketsu is about standardizing the company culture and workplace norms to ensure working environments remain clean, de cluttered and lean. Standardizing best practices so they become the norm is key. Among the ways to accomplish this include.

Benefits:

- Increasing of the awareness and morale,
- Decreasing of mistakes quantity resulting from the inattention,
- Proceedings according to decisions,
- Improvement of the internal communication processes,
- Improvement of the inter-human relations.

3.2.2 Advantages of 5S implementation

The successful implementation and execution of the 5S principles in various organizations results several advantages as mentioned following.

- 5S concept is very simple and easily understood by everyone because this only requires knowledge of the conventional discipline and high commitment. This practice can be implemented at all levels.
- 5S will foster teamwork, discipline and will increase the sense of responsibility and compassion for company.
- 5S will create clean, productive work environments and secure the delivery system towards a world-class.
- On-going commitment from management and involvement are the cornerstone of all citizens for the successful implementation of 5S practices.
- 5S is an on-going need to maintain excellent service delivery performance.
- Assessment of internal audit will normally move the organization to continually repair the quality and effectiveness of services delivered to customers. Activities are planned and on-going audit to help people to be prepared to face the real 5S audits by the MPC to obtain and maintain certification of 5S.

Summary

- Repair maintenance is the repair of an item which has failed or which is showing imminent signs of failure.
- Condition-based maintenance is carried out when an equipment item starts to show early signs of failure or when its performance becomes degraded.
- Reliability centred maintenance (RCM) uses a risk-based approach to organizing maintenance activities. Those items that contribute the most to overall risk receive a higher maintenance priority than those that are considered to be less critical.
- JHA or job safety analysis should be done before work permit is issued.
- When the work is complete all copies of the permit should be returned to the issuing point. Once all the work inspection is done, work permit is closed.
- After a piece of equipment or piping that operates under pressure has been opened and then reassembled (**"buttoned up"**) it must be pressure tested before being put back into service.
- The tightness test is conducted after the item was opened or cleaning, inspection, or routine maintenance. The test ensures that the equipment is leak-free but it does not test the integrity of the vessel or piping itself.
- The strength or hydro test is used when the equipment has been modified, say by having some welding done on it, or when structural repairs have been made.
- Tightness test pressures should not exceed the equipment MAWP or system design pressure or the vessel's relief valve set pressure.
- Risk-based approach to inspection helps ensure that resources are allocated as effectively as possible.
- 5-S system is defined as a method of workplace organization based on five Japanese words; roughly translated as **"sort," "orderliness," "cleanliness," "standardize"** and **"sustain."**
- Seiri (sort) means the necessary and unnecessary materials available in the workplace should be sorted and classified.
- Seiton (orderliness) means preparing the necessary items neatly and systematically so that they can easily be taken and returned in the original place after use.
- Seiso (cleanliness) is essential to create a clean and regular working and living environment.
- Seiketsu (standardize) establish standards of the best practice in the workplace and to ensure that the standards are compiled.
- Shitsuke is about maintaining the improvements done in previous steps. It is about self-discipline to maintain or sustain the changes.

Exercise

1. **What are the 5 phases of 5S?**
   a) Shine, Shut-Up, Sustain, Sort, Standardize
   b) Sustain, Sort, Standardize, Sushi mi, Shine
   c) Standardize, Sort, Sustain, Shine, Set-in-Order
   d) Sort, Sustain, Sushi, Shine, Standardize

2. **What is the purpose of the 5S system in the workplace?**
   a) Cleanliness
   b) Organization
   c) Efficiency
   d) All of the above

3. **This is Distinguishing between necessary and unnecessary things, and getting rid of what you do not need.**
   a) Cleanliness
   b) Sustain
   c) Sorting
   d) Orderliness

4. **This is Setting up standards for a neat, clean, workplace.**
   a) Standardize
   b) Sustain
   c) Sorting
   d) Orderliness

5. **It is all about standardizing the company culture and workplace norms to ensure working environments remain clean, decluttered and lean.**
   a) Cleanliness
   b) Sustain
   c) Standardize
   d) Orderliness

Scan the QR codes or click on the link to watch the related videos

https://youtu.be/9VR_gJ1FAyk
Reliability Centred Maintenance | RCM Explained

Scan the QR codes or click on the link to watch the related videos

https://youtu.be/lRFWeTRAcCU
Pipeline safety

Scan the QR codes or click on the link to watch the related videos

https://youtu.be/CcbogALFNX0
What is 5s?

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

N·S·D·C
National
Skill Development
Corporation
Transforming the skill landscape

HSSC
HYDROCARBON SECTOR
SKILL COUNCIL

4. Working effectively in a team

Unit 4.1 - Working effectively in a team

HYC/N9301

Key Learning Outcomes

At the end of this module, the participant will be able to:

1. Discuss the communication skills.
2. Define the teamwork and communication and handling the work patiently with team and customers.

Unit 4.1 - Working effectively in a team

Unit Objectives

At the end of this unit, the participant will be able to:

1. Identify importance of effective communication.
2. List out essential skills required for effective communication.
3. Identify barriers to effective communication.
4. Define how to work effectively in team.

4.1.1 Effective communication

Effective communication is a process of exchanging ideas, thoughts, knowledge and information such that the purpose or intention is fulfilled in the best possible manner. In simple words, it is nothing but the presentation of views by the sender in a way best understood by the receiver.

We can say that it generally involves;

- **Sender:** The person who initiates the process of communication by sending a message;
- **Receiver:** The one to whom the message is to be delivered.

Characteristics of effective communication

Just delivering a message is not enough; it must meet the purpose of the sender. Keeping this in mind, let us discuss the elements which make communication effective;

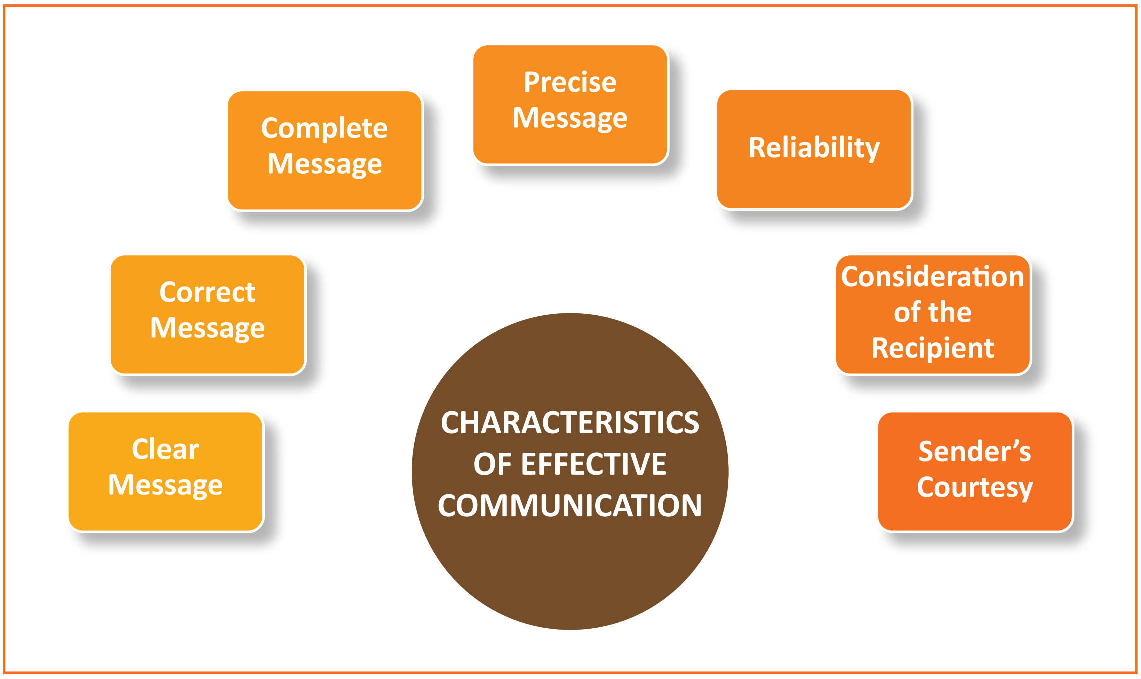

Fig: 4.1.1 Characteristics of effective communication

- **Clear message:** The message which the sender wants to convey must be simple, easy to understand and systematically framed to retain its meaningfulness.
- **Correct message:** The information communicated must not be vague or false in any sense; it must be free from errors and grammatical mistakes.
- **Complete message:** Communication is the base for decision making. If the information is incomplete, it may lead to wrong decisions.
- **Precise message:** The message sent must be short and concise to facilitate straightforward interpretation and take the desired steps.
- **Reliability:** The sender must be sure from his end that whatever he is conveying is right by his knowledge. Even the receiver must have trust on the sender and can rely on the message sent.
- **Consideration of the recipient:** The medium of communication and other physical settings must be planned, keeping in mind the attitude, language, knowledge, education level and position of the receiver.
- **Sender's courtesy:** The message so drafted must reflect the sender's courtesy, humbleness and respect towards the receiver.

Effective communication skills

Conveying a message effectively is an art as well as a skill developed after continuous practice and experience. The predetermined set of skills required for an influential communication process are as follows;

Fig: 4.1.2 Effective communication skills

- **Observance:** A person must possess sharp observing skills to gain more and more knowledge and information.
- **Clarity and brevity:** The message must be drafted in simple words, and it should be clear and precise to create the desired impact over the receiver.
- **Listening and understanding:** The most crucial skill in a person is he must be a good, alert and patient listener. He must be able to understand and interpret the message well.
- **Emotional intelligence:** A person must be emotionally aware and the ability to influence others from within.

- **Self-efficacy:** Also, he/she must have faith in himself and his capabilities to achieve the objectives of communication.
- **Self-confidence:** Being one of the essential communication skills, confidence enhances the worthiness of the message being delivered.
- **Respectfulness:** Delivering a message with courtesy and respecting the values, believes, opinions and ideas of the receiver is the essence of effective communication.
- **Non-verbal communication:** To connect with the receiver in a better way, the sender must involve the non-verbal means communication too. These include gestures, facial expressions, eye contact, postures, etc.
- **Selection of the right medium:** Choice of the correct medium for communication is also a skill. It is necessary to select an appropriate medium according to the situation, priority of the message, the receiver's point of view, etc.
- **Providing feedback:** Effective communication is always a two-way process. A person must take as well as give feedback to bring forward the other person's perspective too.

Barriers to effective communication

There are certain obstacles which sometimes hinder the process of communication, making it less useful for the sender as well as the receiver. These barriers are categorized under three groups. Let us understand these in detail below.

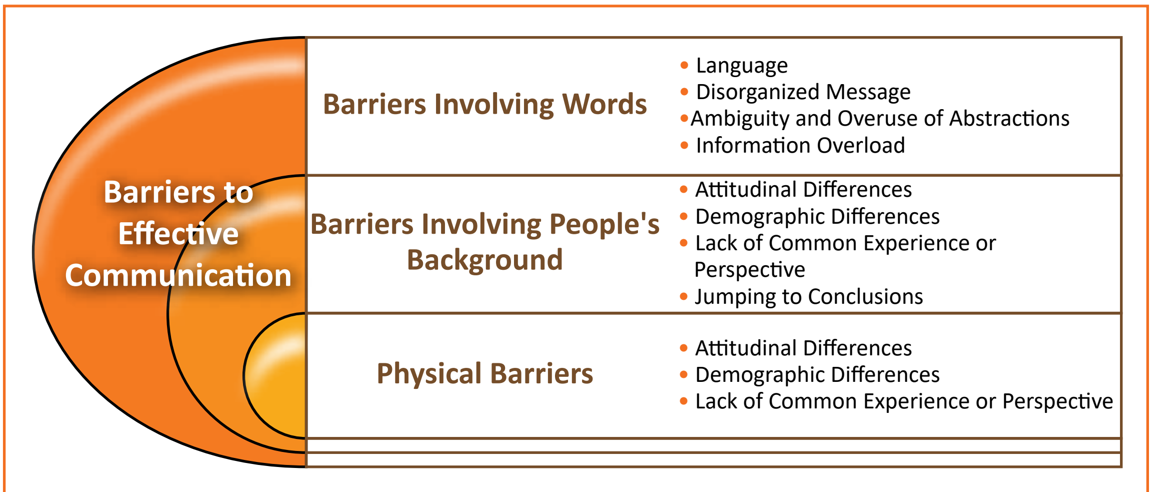

Fig: 4.1.3 Barriers to effective communication

Barriers involving words

Words play an essential role in the process of communication. Any disturbance or distraction in the way a message is presented may lead to miscommunication. Following are the different types of communication barriers related to words.

- **Language:** It is a medium of communication. If the sender is making excessive use of technical terms, it will become difficult for the receiver to understand the message clearly.
- **Ambiguity and overuse of abstractions:** Even if the message is presented in a non-realistic or vague context involving a lot of notions, the receiver won't be able to connect with the idea properly.

- **Disorganized message:** When the words are not organized systematically to form a powerful message, it loses its efficiency and meaning.
- **Information overload:** The effectiveness of communication reduces when a person keeps on speaking for an extended period. Thus, leading to the receiver's exhaustion, who won't be able to keep track of everything that is conveyed.

Barriers involving people's background

People belong to different backgrounds, i.e., Culture, education level, gender, etc. These attributes majorly affect the efficiency of the communication process. It involves the following related obstacles.

- **Attitudinal differences:** At times, people are resistant to understand or change their mind when they have set their views about a particular topic. Their attitude obstructs meeting the purpose of the communication.
- **Demographic differences:** The difference in age, generation, gender, status, tradition, etc., Creates a lack of understanding among people and thus, hinders the process of communication.
- **Lack of common experience or perspective:** The experiences of a person develops their perspective of seeing things in a particular way. This perspective varies from person to person. Therefore, it becomes difficult for a receiver to relate with the sender's experience or views as he might have never gone through it himself.
- **Jumping to conclusions:** Some people lack the patience of listening to others and often jump to conclusions between the communications, thus neglecting the motive of the message.

Physical barriers

These barriers can be experienced directly but challenging to overcome. These include:

- **Physical distance:** When people communicate over long distances, they miss out the non-verbal aspect of communication, since the gestures and expressions of the receiver cannot be interpreted.
- **Noise:** The environment or the communication system sometimes involve unwanted noise which interrupts the process of communication making it inefficient.
- **Physiological barriers:** One of the most common barriers to effective communication is the physical disability of the people involved. Some of these are hearing impairment, poor eyesight, stammering, etc.

Thus, we can say that the significant purpose of communication is to pass on the information to the receiver in such a manner that it does not lose its significance. At the same time, the message must be received in its purest form.

4.1.2 Communicate with supervisor

Good communication with your supervisor is important to both of you. There are five important aspects to remember when communicating with your supervisor.

- You must be able to follow instructions.
- You need to know how to ask questions.
- You should report any problems and results of your work.
- You should accurately record and give messages to your supervisor.
- You need to discuss your job performance.

Following instructions is important at all times, but especially during your training period. Your supervisor will be watching to see how well you do this. Use your senses to follow instructions correctly.

- **Concentrate:** Focus your attention on the supervisor. Don't be distracted by noise and movement.
- **Listen:** pay attention to the words being spoken. If you hear unfamiliar words or terms, ask for clarification. Listening also means interpreting body language, voice inflections, and gestures. If this non-verbal communication is confusing, ask the supervisor to clarify what you don't understand.
- **Watch:** Sometimes a supervisor demonstrates how a task is performed. If necessary, ask the supervisor to repeat the process until you understand it completely. Sometimes a task may be too complex or time-consuming to demonstrate. In such cases, you probably will receive general instructions. If there are details you don't understand, ask for guidance to continue the task.
- **Question:** After you have listened and watched, ask questions. A good supervisor will encourage you to ask questions. It's better to ask a question than to make a mistake because you didn't understand.
- **Write:** Write down in a small notebook the important points to remember about the instructions you get. Don't write while your supervisor is talking or demonstrating something. Do it at a break in the instructions.
- **Practice:** With your supervisor's permission, perform the task. Make sure you have fully completed the job. This may include putting tools away or cleaning up your work area. Don't leave your work partially completed.

4.1.3 Achieve goals in the workplace

Creating goals in the workplace can help you achieve personal and professional success. Setting timeliness and taking steps to reach milestones can help you excel in your role and advance your career.

What is the importance of achieving goals in the workplace?

Setting goals is important because it helps you define how you should move toward achieving professional short- and long-term objectives both for your personal career and your company. They can give you motivation for improving skill sets, learning new skills or growing your responsibilities. Setting and achieving workplace goals can also show management that you are committed to the success of the organization. Some benefits of setting workplace goals are:

- **They give you direction:** A well-planned goal helps you move forward in the direction you need or want to go. For example, if you want to become a sales manager someday, writing down that goal with specifics on what steps you will take to achieve it can help you to begin working on your goal right away.
- **They help you stay on track:** A specific goal gives you a solid plan for accomplishing a task or project. You can look often at your goal to help you stay motivated. For example, if you need to write a training guide for new employees, you can look at the time line needed to reach that goal on a daily or weekly basis. This reminder can help you meet your deadline.
- **They make large projects easier:** You can divide your goals into smaller tasks so you do not become overwhelmed with a large project. For example, writing an entire training guide might seem daunting. However, if you set a goal to write one section of the guide each day or week, you will see progress on the task and feel a sense of accomplishment.
- **They help with time management:** When you have a deadline for a task, setting specific goals for each phase of the project will help you finish the task on time and eliminate distractions.

How to accomplish goals

Use these steps to help you set and achieve workplace goals to advance your career or succeed in your role.

1. **Create goals that inspire you:** When setting workplace goals, choose ones that will inspire you. Think of tasks or accomplishments that will advance your career or relate to your core values. Your desire to accomplish these goals will help you remain motivated and work toward achieving them.

   You can also use rewards to help motivate you to complete your goals. Develop a system to celebrate your progress, such as taking a break or having a snack for achieving small goals during the day, or attending an event or taking a vacation after accomplishing larger goals.
2. **Write down your goals:** Writing out your goals on paper, a calendar or a computer can reinforce them and provide a visual reminder to work toward them. Written goals allow you to access and view them often. To begin achieving your goals, write down each one and create a plan and time line to reach them.
3. **Use smart goals:** Smart goals are a methodology for setting goals that makes them easier to track and accomplish. Using this method gives you clear directions on how to define and plan achieving your goals. Here are the components of a smart goal.

   - **Specific:** This part of the goal-setting process is critical for the success of accomplishing goals. Write the goals in a well-defined and clear manner so that you or anyone else in the workplace can understand them. Always use precise action words. For example, **"increase sales"** or **"earn a promotion"** are unspecific goals, but **"increase sales by 10% this month"** or **"become assistant manager by the end of the year"** are specific goals, and their clarity makes them easier to work toward.

- **Measurable:** Use numbers, dates and other objective criteria when setting your goals so you can measure and view your progress.
- **Achievable:** When you set a goal, check that it is feasible. Look at how much time you have each day, week or month to accomplish a task and set a realistic plan for accomplishing it. Be sure you have the training, tools and resources to achieve the goal.
- **Relevant:** When you are trying to reach goals, especially in the workplace, they should relate to your career and the direction you want to go. Understand your particular skill sets and expertise in the job, and make the goal relevant to them.
- **Time-bound:** Similarly to the measurable aspect of smart goals, you should have a clear time frame for accomplishing every goal. Knowing when a project needs to be completed will help you focus on all the tasks that need to be accomplished to meet the deadline.

4. **Re-evaluate your goals periodically:** It is important to look at the progress of your goals regularly. Depending on the depth of the plan, you can re evaluate daily, weekly, monthly or biannually. Look at the actions you've taken to move forward with your goal, and if they are successful, continue to do those things. If you find that the goal is harder to achieve than you originally planned, make adjustments so you can increase your progress.

   For example, if you have committed to writing five blog posts per week for the company website, and you are finding it difficult to accomplish those numbers, try writing only four posts per week or changing your schedule so you have more time to write. Speak with your team members or management and get approval for the new plan.

5. **Keep striving toward your goals:** As you move toward accomplishing your goals, you want to maintain the excitement of and commitment to achieving them. Here are a few things to keep in mind when you are accomplishing your goals.

   - **Be excited about the process:** One of the reasons you created goals was because you wanted a change. Stay passionate about the **"why"** of your goal. Keep positive on the small steps you are making toward the plan, and reward yourself when a time-bound goal is met.
   - **Find support and encouragement:** Surround yourself with people who encourage you to accomplish your goals. Spend time with positive co workers, friends, family members and others who believe in what you are trying to achieve. A kind and encouraging word can inspire you to keep moving toward the completion of your goal.
   - **Visualize your success:** One of the best aspects of goal setting is enjoying the results at the end. Always visualize yourself succeeding, and use your goals to help you be happy and successful in the workplace.

4.1.4 Work effectively in a team

When a mix of people with different skills and varying levels of experience are pulled together in a team, it can lead to more effective and innovative solutions, which is great news for businesses. Employees can often feel happier being part of something bigger too, which can lead to higher productivity and lower staff turnover. As a result, team working is an important skill that employers often look for in job candidates. It's therefore a skill you shouldn't overlook.

Tips to improve your teamwork

Working with other people may seem simple enough but working in a team can be a complicated dynamic to navigate effectively. Here are nine key tips you should follow to improve your team working skills.

1. **Get into the right mindset:** Working alone means that you can set your own schedule and tackle tasks in a way that suits you best. In a team, you need to share ideas, divide workloads and go with group consensuses for decisions. By understanding this shift and accepting the differences, you will be able to set the right mindset and get stuck into the new team dynamic.
2. **Understand what's required of you:** Before you begin, make sure you understand your role, responsibilities in the team, deadlines, how everyone plans to work together, why the team was created, the teamwork processes and practices as well as what the ultimate goal of the team is. By doing this, you will be able to contribute much more effectively.
3. **Put in 100% effort:** Don't hide behind others or let other team members take on the bulk of the work. Be prepared to put in an equal amount of effort as others, so you complete the work assigned to you within the time frame that's been set. A good team player would also notice when others are struggling and help. The overall team will perform better as a result.
4. **Communicate, communicate and communicate:** The importance of communication in a team can't be underestimated. It's vital that everyone shares their progress and raises issues quickly so they can be dealt with. Don't forget that communication isn't just about talking but listening to others too. Without this level of open and honest conversation, problems may be missed, and projects can rapidly fall behind.
5. **Share your ideas:** When you've come up with an exciting new idea, you may want to rush to your boss to share it. But when working as a team, you must share your ideas and resources with your team members. Arguing afterwards over who gets the credit won't do any favours for you, as your boss will see that you're not a team player.
6. **Keep an open mind:** Brainstorming as a team is a great way to come up with a range of new and exciting ideas. While you may think your idea is the best, others might not always agree with you. You may also not agree with everyone else's ideas. Don't be difficult or overly negative about other people's ideas. Understand that everyone has the right to their own opinions and as a team, you will go with the consensus.
7. **Get to know each other:** Take time to get to know the rest of your team. This will make it much easier for you all to work together effectively going forward. There may be instances when you don't get on with a certain team member, but for the benefit of everyone, it's important that you always try and remain professional.
8. **Stay positive:** Don't complain all the time or place blame on single members of the team. You're

all in it together. If you notice the morale is dropping, provide encouragement where needed. Take time to celebrate your team's achievements too. A happier, more positive team will work much better together and achieve even better results.

9. **Be adaptable:** When working on a project, deliverables may change, team members may come and go, or you may face unexpected obstacles. You need to be someone who can adapt quickly to new situations, which will ensure the team continues to work together effectively.

Summary

- Effective communication is a process of exchanging ideas, thoughts, knowledge and information such that the purpose or intention is fulfilled in the best possible manner.
- Listening and understanding is the most crucial skill in a person is he must be a good, alert and patient listener.
- The effective communication certain characteristics such as clear, correct, precise, complete, and reliable message.
- Non-verbal communication includes, gestures, facial expressions, eye-contact, postures, etc.
- Effective communication is always a two-way process and providing feedback is an essential part of it.
- Certain obstacles sometimes hinder the process of communication, language barriers, ambiguity, overuse of abstractions, information overload.
- Physiological barriers are the physical disability of the people involved. Some of these are hearing impairment, poor eyesight, stammering, etc.
- Goal setting gives direction and help with time management.
- Smart goals are a methodology for setting goals that makes them easier to track and accomplish.
- Working effectively in a team can lead to more effective and innovative solutions at workplace

Exercise

1. **The clear exchange of ideas and information is ....**

a) Listening	b) Communication
c) Sympathy	d) Social isolation

2. **The characteristics of communication when the sender must be sure from his end that whatever he is conveying is right by his knowledge is called ....**

a) Correct message	b) Complete message
c) Reliability	d) Sender's Courtesy

3. **Which type of barriers to effective communication is the physical disability of the people to communicate effectively?**
   a) Noise
   b) Physiological Barriers
   c) Physical Barriers
   d) Emotional Barriers

4. **SMART goals are a methodology for setting goals that makes them easier to track and accomplish. What does S stand for in SMART?**
   a) Sales
   b) Specific
   c) Smart
   d) Seamless

5. **.. as a team is a great way to come up with a range of new and exciting ideas.**
   a) Reflection
   b) Staying positive
   c) Brainstorming
   d) Communication

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5. Maintain health, safety and security procedures

HYDROCARBON SECTOR SKILL COUNCIL

Unit 5.1 - Maintain health, safety and security procedures

HYC/N9302

Key Learning Outcomes

At the end of this module, the participant will be able to:

1. Identify the importance of promoting a safe working environment.
2. Identify how to reduce risk.
3. Define hospital electrical safety measures.
4. Define hospital fire safety measures.
5. Define hospital environment safety measures.
6. Explain medical emergencies.
7. Explain the procedure of dealing with medical emergency.
8. Identify the basic fire awareness.
9. Explain the first aid process.
10. Explain the cardiopulmonary resuscitation (CPR) process.

Unit 5.1 - Maintain a Safe Working Environment

Unit Objectives

At the end of this unit, the participant will be able to:

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2. Identify how to reduce risk.
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9. Explain the first aid process.
10. Explain the cardiopulmonary resuscitation (CPR) process.

5.1.1 Introduction

Commitment to health and safety should be at the top. Everyone at a workplace, including employer, supervisor, workers, employees and customers must take the responsibility to promote health, hygiene and safety.

Definition of health

As defined by the World Health Organization (WHO), health is a “state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity’’.

Definition of safety

Safety is the state of being ‘safe’, the condition of being protected from harm or other non-desirable outcomes. Regular risk assessments should be conducted at retail stores to identify health and safety problems, and initiate necessary measures to eliminate or mitigate them as far as possible.

5.1.2. Health and safety requirements

It is imperative to ensure that the retail space is safe for everyone in the area especially for employees and the customers. It is always expected from every sales associate to identify and follow health and safety needs laid down by the retailer and the law, which are in place to act as a monitor to avoid all kinds of health or safety hazards.

Following are the factors to keep in mind while undertaking health and safety measures at a retail store:

1. **Abiding by the law:** A retailer has to show that he or she is following all safety practices in his retail store.
2. **Risk assessment:** A risk assessment examines the hazardous conditions at a workplace to identify risks and implement measures to prevent or reduce the risks.
3. **Safety readiness from expected perils:** As per the health and safety legislation, it is required to follow health and safety rules.
4. **Ergonomics:** It is the science of matching a retail store's requirements to the retailer's capabilities. For example, if a retailer hires a weak person to lift heavy boxes for hours on end, there are more chances of risk injury to the employee due to poor ergonomics.
5. **Air quality:** Without inadequate ventilation, air starts to collect mold, fungus, bacteria or odours in a retail store. Law recommends installing machines that cycle fresh outdoor air and circulates it throughout the store.
6. **Visual inspection of premise:** As per the law, it is important to visually inspect the store premises to ensure no hazards are visible, which include uneven flooring, spills and misplaced boxes.
7. **Crime:** The retailer should install a surveillance camera in different parts of the store for safety purposes. Hiring a guard may also help monitor the store.
8. **Training:** Employees of the retail store should be trained to tackle any situation inviting danger.
9. **Insurance:** The retailer must get the retail store insured.

5.1.3 Promoting a safe working environment

The fundamental goal of any safety program is to ensure that workers are not exposed to sources of energy such as high-voltage electricity, high-temperature fluids, toxic chemicals, moving parts, or falls from heights. Therefore, before working on a piece of equipment, the associated sources of high energy must be identified and secured. In the case of a pump, e.g., The following energy sources are probably present.

- **Rotating energy:** The driver, drive shaft, and impeller all turn. It is important that they be secured from inadvertent movement (even if the motor has been de-energized) before anyone works on the pump.
- **Electrical energy:** If the pump has an electrically driven motor, the electricity supply to it must be properly isolated.
- **Heat energy:** If the pump is driven by a steam turbine, or if there is steam tracing around it, it is important to ensure that the steam, and the associated steam condensate system are properly isolated.
- **Chemical energy:** If the pump normally handles hazardous chemicals that are toxic or a health hazard, it has to be properly cleared of them.

- **Flammable/explosive energy:** If the pump handles hydrocarbons, or other materials that could ignite, they have to be cleared, often using an inert gas such as nitrogen.
- **Potential energy:** If the pump is not located at grade, it may be possible for a person to fall off it (and if it is at grade there may be a pit below it).

Energy control procedures can be placed into one of the four categories shown - below (in the preferred order).

- Removal of the hazard.
- Positive isolation of the hazard.
- Lockout/tagout of the hazard.
- Administrative controls.

Venting and draining requirements

- Equipment and systems, provided with isolation for servicing, should be equipped with vent and drain valves as required to relieve pressure and remove fluids from the isolated equipment.
- Isolated components containing high pressure or a significant volume of vapour should be equipped with a vent valve. If the potential exists for venting of a significant volume of vapour the vent should be tied into the appropriate flare or vent system. For high-pressure services, the vent should include a throttling valve in addition to the isolation valve to control the rate of venting.
- Isolated components containing a significant volume of liquid should be equipped with a drain valve. If the volume of liquid is large, the drain should include a throttling valve in addition to the isolation valve to control the rate of draining and to prevent large volume gas blow by to the drain system.

Manways

When removing the first manway, the following guidelines can be used:

- Loosen bolting on the manway and remove all but four bolts. These are at the 12, 3, 6, and 9 o'clock positions.
- The last bolts on the manway should be loosened and carefully spread open to ensure that there is no pressure trapped in the vessel.
- When it is confirmed that there is no residual pressure in the vessel, the four bolts can be removed, and the manway taken off.

Electrical equipment

Electrical equipment can be isolated as follows:

- Shut down the equipment using the selector switch followed by the master disconnect.
- Ensure that all power sources are locked and tagged out.
- Stored electrical energy must be discharged to obtain zero energy state.
- When working on or near exposed de-energized electrical equipment, a qualified person should use test equipment to ensure that all circuits are dead.

Mechanical equipment

- Release or block all stored mechanical energy including that contained in springs and items under tension.
- Use blocks, pins, or chains to restrain energy when equipment cannot be brought to a zero potential energy state.
- Padlocks, lockouts, blinds, and tags should be used to lockout and tagout mechanical energy.
- If additional energy sources are present, follow the applicable methods of energy isolation listed in this section.

Pipe plugs

Plugs are sometimes used in pipeline repair; they create a vapour barrier when a line has been isolated and de-pressured, but has not been completely cleared of flammable, combustible, or toxic materials. Expandable plugs are also used to isolate sections of gravity drain systems such as sewers. Examples include plumbers plugs - which consist of two parallel disks that compress an elastic material together to form a seal on the inside diameter of the pipe - and inflatable bladders - which are inflated either pneumatically or hydraulically

5.1.4 How to Reduce Risk

To reduce risk, you must:

- Make sure that your own health and hygiene does not pose a risk to others.
- Make sure that your seniors know where you are.
- Check for health, safety and security risks when working and report if you see any hazards.
- **Use approved procedures when carrying out work that could be dangerous including:**
  1. Correct moving and handling techniques.
  2. Appropriate hygiene procedures.
  3. Correct protective clothing for the situation, environment and activities.
  4. Storing equipment and materials and dealing with spillages and getting rid of waste.
- **Take immediate and appropriate action to deal with emergencies, including:**
  1. Security problems.
  2. Accidents.
  3. Fire.
- **Use your skills and experience until appropriate help arrives: You must:**
  1. Call for the appropriate help.
  2. Continue to provide help until someone who is qualified to deal with the emergency is available.
  3. Support patients and others including family carers who may be affected by the emergency.
  4. Record and report incidents and emergencies accurately and fully in line with your organisation's policies.

5.1.5 Near misses and dangerous occurrences

Not only is the investigation of accidents and incidents important, it is also useful to investigate near misses and dangerous occurrences which did not result in injury. Just because no- one has been injured on one occasion does not mean that if the event happened again the result would be the same.

Whether the incident is classed as an accident, a near miss or a dangerous occurrence, the investigation should carry the same degree of importance, and the findings will be as useful in any event in preventing a recurrence. Specific lessons should be noted to identify why control measures already in place failed to prevent the incident and what further measures should be introduced to rectify the situation. General lessons learned from one incident will also be useful throughout an organization to increase awareness about health and safety issues.

5.1.6 Categorizing incidents

Hazards related to oil and gas industry

Hazards in oil and gas industry can be divided into two broad categories:

1. **Safety and injury hazards:** Workers in oil and gas industry are generally susceptible to the following safety and injury hazards.

Safety and Injured Hazard	Possible Causes
Motor Vehicle Accident	• Often the roads leading to well sites lack firm shoulders and other safety features. • Fatigue due to long driving distance and long working shifts.
Contact Injuries	• Workers being stuck by, entangled, or crushed by tools, machinery or other objects.
Fire and explosions	• Presence of highly combustible hydrocarbons. • Presence of oxygen/ignition source.
Slip, Trips and Falls	• Frequent need to work at elevations. • Uneven Surface. • Improper use or non-availability of fall protection systems.
Confined Space	**According to NIOHS, confined space refers to space, which by design has:** • Limited openings for entry and exit. • Unfavourable natural ventilation. • Not designed for continuous employee occupancy. Example of confined space in Oil and Gas Industry are storage tanks, pipelines, Silos, etc.

Table: 5.1.1 Possible cause of injure/hazard

2. Workers in oil and gas industry are generally susceptible to following agents which lead to various health and illnesses hazard, chemical hazards (toxic, corrosive, carcinogens, asphyxiates, irritant and sensitizing substances); physical hazards (noise, vibration, radiations, extreme temperature); biological hazards (virus, parasites, bacteria); ergonomic hazards (manual handling activities, repetitive motions, awkward postures); and psychosocial hazards (overwork, odd working hours, isolated sites, violence).

   The following table identifies the potential health effects from key processes in oil and gas industry:

Segments	Key Processes	Agents	Possible Health Effects
Upstream	• Seismic Survey and evalution • Exploring drilling • Development and production • Decommissioning	• Pathogenic microorganisms • Infected transmitting vectors • Drilling mud • Petroleum products (Hydrocarbons) • Radioactive sources • Chemical and additives • Extream temperatures • Silica/Asbestos • Nois/Vibration • Mechanical • Ergonomic • Psychosocial	• Infectious and parasitic diseases (e.g., Hepatitis A, Cholera, Typhoid Fever) • Cumulative trauma disorders • Chronic obstructive pulmonary disease • Gastrointestinal disorders • Dermal and eye issues • Spinal Disorders • Neoplasms/Cancer • Heat Stroke • Stress • Sleep deficits • Noise induces hearing loss • Drug and alcohol abuse
Midstream	• Pipelines • Transport and storage • Marketing	• Petroleum products (Hydrocarbons) • Dust from filling and scalling from cleaning of pipes and tanks)	• Dermal and eye issue • Pulmonary disorders • Gastrontestinal disorders • Neoplasms/Cancer
Midstream	• Products refining • Petro chemicals • Sales and Distribution	• Petroleum products (Hydrocarbons) • Treatment chemicals • Metals (Pb, Cd, Mn, etc.) • Silica/Asbestos • Solvents • Noise/Vibrations	• Dermal and eye issue • Pulmonary disorders • Gastrontestinal disorders • Neoplasms/Cancer • Noise induces hearing loss

Fig: 5.1.1 Potential health effects from key processes

5.1.7 Managing occupational safety and health risks

The aim of occupational safety and health risk management is to identify and assess safety and health hazards existing at the workplace and to define appropriate control and retrieval steps.

Business processes in oil and gas industry are very complex. Hence it is essential that a systematized approach should be used for managing occupational safety and health hazards. Its solution model can be based on the PDCA cycle.

Fig: 5.1.2 PDCA Cycle

5.1.8 Risk management process

Risk management is crucial for preventing work related injury and illness. It includes:

- Identifying the risks.
- Evaluating and prioritizing the risks.
- Implementing preventive/protective measures to control the risk.

There are a number of circumstances in the oil and gas industry where a proper risk management process is essential. For example:

- **Job safety analysis:** It is a process of systematically evaluating certain jobs, tasks, processes or procedures and eliminating or reducing the risks or hazards to as low as reasonably practical (ALARP) in order to protect workers from injury or illness.
- Workplace inspections and audits.

- **Change management:** Identification of new hazards, introduction of new equipment/process, or regulatory needs.

Generally risk management process in the oil and gas industry involves the following key steps:

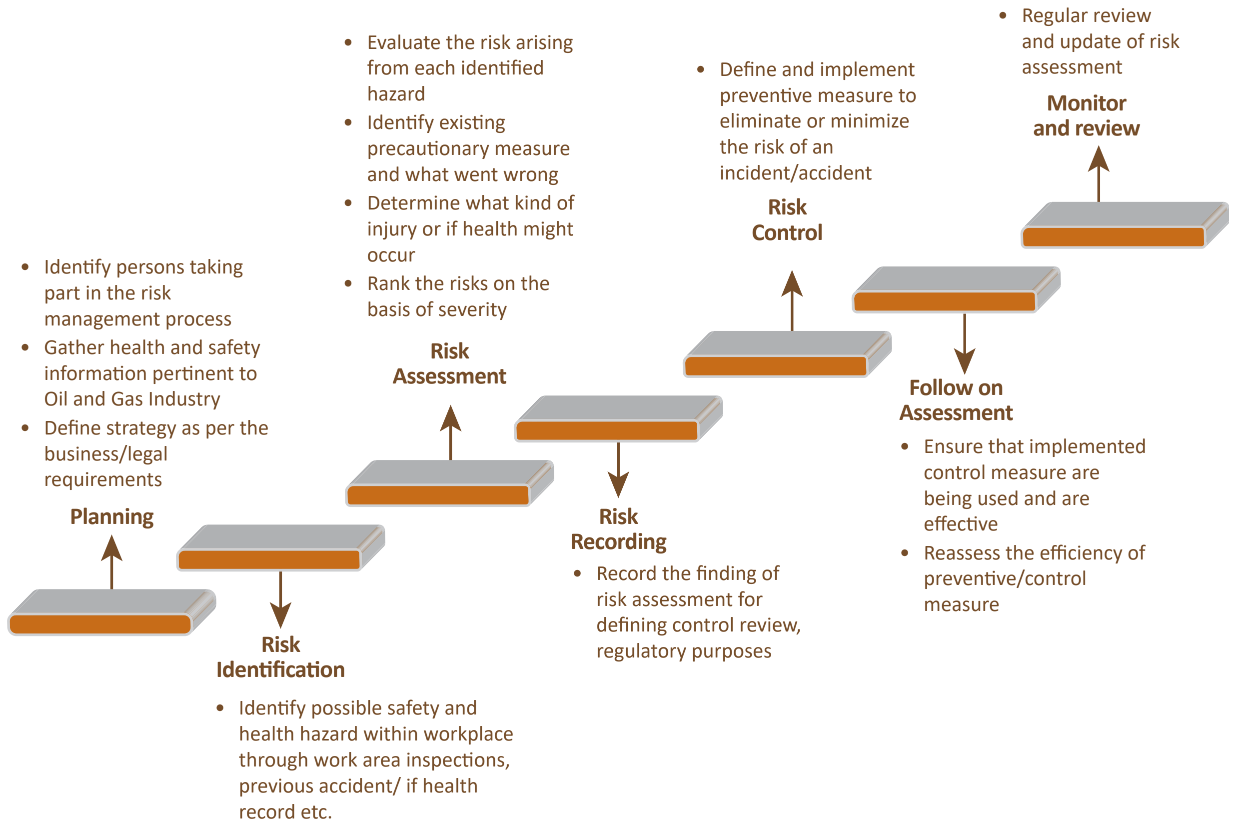


Fig: 5.1.3 Risk Management process

5.1.9 Personal protective equipment (PPE)

Personal protective equipment (PPE) is a clothing or equipment worn by workers to protect them from fire, exposure to toxic chemicals and direct impact. PPE should only be used when engineering designs and operating or maintenance practices do not provide a sufficiently safe work environment.

The need for PPE can be determined with a risk analysis, which will be structured along the following lines:

- Can the hazard be removed? If so, there will be no need for PPE.
- Can the consequences of the hazard be reduced? If so, it may be possible to work with a lower level of PPE.
- Can the likelihood of occurrence be reduced? This may not change PPE requirements, but it will reduce the chance of someone being injured.

Only when the above analysis has been completed, should consideration be given to the types of PPE to be used. A job hazards analysis (JHA) will help determine what type of PPE is needed and when and where it should be worn.

Clothing

Proper clothing will help keep acidic, corrosive, oily, dirty, or dusty materials off the body. Even if clothing with special PPE capabilities is not required, the following rules should be observed at all times and in all work site locations.

- Shorts are never permitted. Workers should always wear full-length pants (trousers) that cover the entire leg.
- Full cover shoes should always be worn. They should have non slip soles. Many companies require that shoes always have toe protection - often in the form of a steel toe cap.
- Hard hats should always be worn.

The effectiveness of clothing with regard to safety and health is affected by the following three factors:

- **Insulation:** High insulation is generally desired in cold weather and not wanted when temperatures are high.
- **Permeability:** This is the measure of the resistance to water vapour movement throughout the clothing.
- **Ventilation:** The ability of ambient air to move throughout the fabric itself or through garment openings.

Flame-resistant clothing

If normal clothing catches fire, it will continue to burn even if the ignition source is removed or if the affected worker moves away from the fire. Flame-resistant material self-extinguishes on removal of the ignition source. Clothing made of flame-resistant material is known as flame-resistant clothing (FRC), which will not continue to burn in such situations, nor will it melt like some synthetic fabrics.

It is used to make coveralls, lab coats, and fire hoods, and is now routinely worn by workers on process facilities at all times. It is also worn by workers who come in contact with energized electrical equipment.

- **Impervious clothing:** Impervious clothing provides protection from splash and should be worn during jobs where it is possible to come in contact with highly acidic or corrosive materials.

  Such jobs may include the following:

  1. Breaking lines.
  2. Opening equipment.
  3. Jobs where liquid materials could splash or spray.

  Workers wearing impervious clothing are more likely to suffer from heat stress.

- **Laboratory clothing:** The clothing requirements for laboratory work will depend on the materials being handled.

  Laboratory workers often handle hazardous chemicals directly; therefore, they will often be required to wear coats, goggles, and chemical-resistant gloves.

Emergency PPE

Emergency responders need specialized PPE in order to fight fires and to enter areas that may be contaminated with toxic chemicals.

- **Fire fighter protective clothing:** Fire fighter protective clothing, sometimes referred to as bunker gear, is worn by all members of fire teams and helideck fire guards. (Only those who are properly trained should wear this type of clothing.) Its use is required for those fighting fires beyond the incipient stage.

  The type of clothing will vary according to the local environment. However, the following should be the minimum requirements:

  1. Fire coat and/or leggings. The coat should be of knee length.
  2. Insulated fire boots - at least calf height with non slip sole tread and reinforced safety toe cap.
  3. Safety gloves.
  4. Self-contained breathing apparatus (SCBAS) for entering smoky areas.

  Fire fighter clothing should not restrict the person's movements. It should also be stored such that it cannot be contaminated or affected by heat, sunlight, or dampness.

- **Proximity suits:** heat-reflecting proximity suits are used by properly trained persons for taking actions such as closing a critical valve that is located close to a fire that has not yet been extinguished. On many offshore platforms, at least one person wearing a proximity suit will be on the helideck when helicopters are landing and taking off.

  Fire entry suits are used for entering flame areas but only for precise snatch rescue work where the casualty location is known and not for fire fighting under any circumstance.

Respiratory protection

Although every attempt should be made to make sure that workers are never exposed to toxic or harmful vapours, there will be times when some form of respiratory protection is needed, if only as a precaution.

- **Fixed breathing air systems:** Respiratory protective equipment should be used in areas that do not have a safe breathing environment, or where there is the possibility of an unexpected release of toxic gas or particulates.

  When respirators are used in atmospheres where the concentration of toxic gases could approach the immediately damaging to life and health (IDLH) level, standby personnel carrying SCBA should be present, along with suitable rescue equipment such as harnesses and hoists.

- **Respirators: the five most widely used types of respirator are as follows:**

  1. **Air-purifying respirators:** Air-purifying respirators contain material that traps and purifies the air that the worker is breathing. They can trap either solid materials (particulates or dust) or toxic gases depending on the material used in the filter. Respirators of this type can be single or multiple use (replacement cartridges are put into the respirator for multiple use). In general, respirators in this category do not provide a high level of protection and should not be used when the concentration of toxic gas is close to IDLH (immediately dangerous to life or health).

2. **Supplied air respirators:** Supplied air respirators are connected via a hose to a supply of air. The air can come from a compressor or from cylinders. (If a compressor is used, it is essential that the air supply cannot become contaminated by fumes in the area.) Respirators of this type are safer than any type of system that purifies air because they do not rely on trapping or containing hazardous chemicals.
3. **Self-contained breathing apparatus (SCBA):** SCBAS are similar to supplied air respirators except that the air is supplied from a cylinder, usually carried by the worker. They are used for short-duration tasks, emergency rescue, escape, and process control procedures. The air supply is generally rated for 30 minutes, but this time is reduced if the work being performed is strenuous.
4. SCBAS should be inspected before each use; emergency units should be inspected at least monthly.
5. **Chemical canister re breathers:** Chemical canister re breathers are used only for emergency egress. The canister contains a special chemical that evolves as oxygen when contacted by the moisture and carbon dioxide in exhaled breath (the co2 and moisture are retained).
6. They are suitable for high concentrations of contaminants and oxygen deficient atmospheres, but they are negative-pressure respirators that rely upon a perfect face-to-mask seal, which limits their use to emergency situations only.
7. **Disposable respirators:** These are intended for single use. They are primarily used for protection against nuisance dusts and non-toxic particles.

Use of respirators

Before using a respirator, the following checks should be carried out:

- The respirator should be checked for correct fitness before every use.
- Employees should not wear items such as facial hair or eyeglasses that could prevent a good seal. Employees who wear prescription glasses while working should be provided with specially designed units.
- All respirators should be inspected before each use to assure all parts are present and in good working order. There should be no cracks in the rubber or lenses and head straps should be properly elastic. Hoses should be checked by being stretched and then looking for cracks.
- A check for leaks should be carried out by covering the mask with the palms of the hands and then inhaling gently. If the mask is pulled toward the face then the fit is good. The leak check is particularly important for negative pressure respirators.
- The pressure in SCBA tanks should be as specified. The regulator pressure should be about the same as that of the cylinder. The low-pressure alarm should be checked.

Head protection

Hard hats/helmets protect the head from impact and penetration from falling or flying objects, overhead spills of hot or hazardous liquids, and electric shock.

They should be worn at:

- Construction sites.
- When near lifting operations or overhead work.
- All process plant areas.

Hard hats are made of rigid plastic, sometimes with a mid line reinforcement ridge. Different styles are available (those made in the form of a traditional cowboy hat are often not permitted on process facilities).

Inside the helmet is a suspension that spreads the helmet's weight over the top of the head and that also provides a space of approximately 30 millimetre between the helmet's shell and the wearer's head so that if an object strikes the shell, the impact is less likely to be transmitted directly to the skull. The suspension generally has an adjustment knob or strap so that the hat can be used for different head sizes.

Hand protection

Gloves should be worn when hands are exposed to hazardous substances or to sharp, rough, or hot objects. The following types of glove are used.

- Leather palm gloves are often worn when carrying out heavy duty work. They resist heat, sparks, sharp, and rough objects, and provide some cushioning against blows, but they provide minimal protection from hydrocarbons and liquids.
- Impervious gloves are made of materials such as neoprene, PVC, or nitrile. They are used when handling hydrocarbons or corrosive chemicals such as acids and caustic.
- Gauntlet-type gloves, which extend above the cuff and protect the wrist and forearm, should be worn when there is a possibility of splashing.
- Cotton gloves protect against dirt and abrasion but are not heavy enough for use with rough or sharp materials.
- Latex gloves provide for maximum dexterity but provide limited protection.
- They are used in light service, such as laboratory work and to keep oil, grease, and liquids off the skin.
- Welders gloves are made from treated leather that provides protection against heat, welding sparks, splatter, and hot slag.
- Insulated gloves are used in laboratories for handling distillation pots and other hot objects.
- Electrician gloves protect against electrical shock.

Foot protection

Shoes used in process facilities should be notched or grooved to prevent slipping on oily or wet surfaces. They should also have a heel to assist with climbing ladders. Boots or shoes with steel toe caps should be used when a dropped object could crush a person's foot.

The following guidelines should be considered:

- Soles should be notched or grooved to prevent slipping on oily or wet surfaces.
- Boots or shoes should have oil-resistant soles and a heel.

- Rubber boots or overshoes can be worn to protect the feet and shoes from excessive water, oil, muck, or corrosive material.
- **Footwear of the following types should not be worn:**
- Tennis and deck styles.
- Deep lug and hiking style soles.
- Crepe soles.
- Smooth leather soles.
- Western style or narrow throat boots.
- Lace-up and zipper style boot higher than 8 inches.
- Slip-on boot higher than 12 inches.

Eye protection

- Eye protection should be used when there is a reasonable probability of eye injury.
- Employers must ensure that each affected employee uses appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapours, or potentially injurious light radiation.
- Employers must ensure that each affected employee uses eye protection that provides side protection when there is a hazard from flying objects.
- Detachable side protectors (e.g., Clip-on or slide-on side shields) meeting the pertinent requirements of this section are acceptable.
- Employers must ensure that each affected employee who wears prescription lenses while engaged in operations that involve eye hazards wears eye protection that incorporates the prescription in its design or wears eye protection that can be worn over the prescription lenses without disturbing the proper position of the prescription lenses or the protective lenses.
- Employers must ensure that each affected employee uses equipment with filter lenses that have a shade number appropriate for the work being performed for protection from injurious light radiation.

Safety glasses

In general, safety glasses should be worn whenever a person is working outside at a process facility, working indoors with hazardous chemicals, and in most non office work areas. Prescriptive lenses must comply with the overall safety glass policy.

Chemical goggles

Chemical goggles protect against splashing liquids, flying solids, and other harmful materials. Examples of work that may require chemical goggles are the following.

- Light chipping.
- Dusty work.
- Cutting wire.

- Using grinders.
- Handling mineral wool or fibreglass.
- Handling hazardous liquids.

5.1.10 Signs

Signs are widely used throughout the process industries to advise people of hazardous conditions and to provide directions as to what actions to take in various situations. It should, however, be remembered that **"red lights don't stop cars - brakes stop cars"**; it is always best to engineer a solution to a hazard than to warn people about that hazard.

Training programs should include an explanation of the signs that are used by the company.

Where possible signs should be symbolic only, i.e., They should not contain wording. This policy reduces problems communicating with an international workforce. However, some signs that use symbols only can be confusing. For example, the **"falling rock"** sign would appear to warn against rocks falling on vehicles. In fact, it is more to do with the fact that fallen rocks may be on the roadway. If supplemental wording is necessary, then all the languages that are typically used at the site should be included.

Types of sign

Guidance as to the types of signs and their meanings is provided in the following sections.

Fig: 5.1.4 Prohibition Sign

Prohibition

Prohibition signs mean **"you must not"** or **"do not do. . .,"** Or **"stop."** Signs of this type have a red circle, a white interior, and a red bar, the sign can be supplemented with more specific information.

Other examples of prohibition signs include the following:

Other examples of prohibition signs include the following:

- No smoking.
- No open flames.
- Non-potable water.
- Prohibition sign.
- Prohibition sign with information.
- Do not enter.
- Do not fish.
- Do not use crane for personnel transfer.

Fig: 5.1.5 Example of prohibition sign

Mandatory action

Mandatory signs mean **"you must do. . ."** Or **"carry out this action,"** or simply

Fig: 5.1.6 Mandatory Sign

"obey." They are often used when special PPE (personal protective equipment) is required.

Other examples of mandatory signs include the following:

- Hearing protection required.
- Wash hands.
- Chock wheels.
- Ground fuel truck.
- Hard hat area.
- Doors must be kept closed.
- Goggles required.
- Face shield required.

Warning

Warning signs are yellow triangles using black lettering.

Other examples of warning signs include:

- H2s gas.
- Corrosive liquids.
- Radiation.
- Equipment automatic start.
- Open trenches.
- High temperature.
- Flammables.

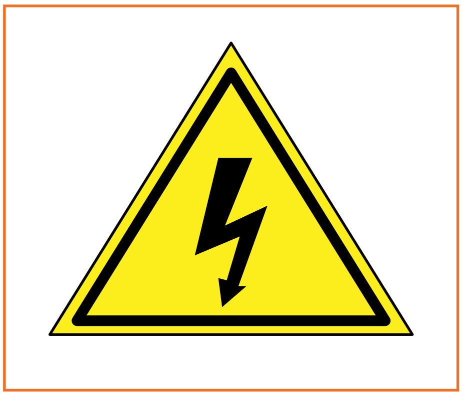


Fig: 5.1.7 Warning Sign

Safe condition

A green square or rectangle indicates a safe condition, a means of escape or the location of safety equipment.

Other examples of safe condition signs include:

- Emergency shower station.
- Emergency eyewash station.
- Potable water.
- Emergency shut down.
- First aid.
- Trash.

Fig: 5.1.8 Fire Safety Sign

Fire safety

Red square or rectangle is to do with fire safety.

Fig: 5.1.9 Fire exit sign

5.1.11 Medical emergencies

Everyone plans for emergencies. That is the reason why we keep a first aid kit with ourselves. At work, however one is exposed to a lot of stress and physical activity. This could lead to certain medical emergencies. It's better to be prepared with the first aid measures and knowledge of implementing them on ourselves and on others. This module equips you with that information. Pay attention to these medical emergency procedures to understand how to conduct you in theses crucial movements. Pay attention during these sessions.

Dealing with medical emergency

A medical emergency is an accidental injury or a medical crisis that is severe. These could be situation where.

- The person is not breathing.
- Stroke or heart attack.
- Severe bleeding.
- Shock.
- Poisoning.
- Burns.

A medical emergency requires your immediate attention, sometimes even before you call emergency services for help.

It is crucial that you know the emergency medical service (ems) number, for your own safety and the safety of others.

Do not

- Give the victim anything to eat or drink.
- Hold the victim.
- Splash or pour any liquid on the victim's face.
- Shift the victim to another place (unless it is the only option to safeguard the victim from the injury).

Bleeding

- Put pressure to the wound with a pressure bandage. Raise the wounded portion to slow the bleeding.
- Pressure the associated points if necessary then apply an additional pressure to reduce the bleeding.

Fainting

- Fainting is a small loss of consciousness which is caused by a momentary reduction of the blood flow to the brain.
- A small loss of consciousness can cause the person to fall.
- A very slow pulse.
- Cold skin with sweat and pale appearance.

Causes of fainting:

1. Taking in too little quantity of foodstuff and liquids (dehydration).
2. Low BP.
3. Deprivation of sleep.
4. Fatigue.

First aid for fainting:

1. Place the victim lying on his/her back and raise his/her legs above the heart level.
2. Check the victim's airway to ensure it is clear.
3. Check for the indications of breathing, coughing, or movement.
4. Loosen clothing (neck ties, collars, belts etc.).
5. If consciousness is not regained within one minute call ems.

Shock

Shock occurs with the failure of the circulatory system due to which insufficient oxygen reaches the tissues. If this condition is not treated immediately, important organs can fail, which can ultimately lead to death. Fear and pain makes effect of shock worse.

First aid for shock:

1. Place the victims resting down (if feasible).
2. Raise the legs 10-12 inches, unless you doubt for a back injury or broken bones.
3. Cover the victim to preserve the body temperature.
4. Give the victim room for fresh air.
5. If victim wants to vomit then- position him/her on his/her left side.
6. Loosen restrictive clothing.

Muscle cramps

- Stretch out the cramped muscle to neutralize the cramp.
- Give massage to the cramped muscle rigidly.
- Apply hot water bottle to the affected area.
- Seek medical help if the cramp continues.
- Avoid unnecessary movements and activities which can cause pain.
- Apply some ice which will help in reducing pain and swelling.
- Apply light pressure with an elastic wrap or a bandage which can also help in reducing the swelling.
- Raise the cramped limb at the level of the heart which further reduces pain and swelling.

Fractures

A fracture is a break or crack in the continuity of the bone.

Dislocation

A dislocation is the displacement of one or a lot of bones at a joint. It usually happens in the shoulders, elbow, thumb, fingers and also the lower jaw.

First aid for dislocations & fractures:

1. Immobilize the effected part.
2. Stabilise the effected part.
3. Use a cloth as a sling.
4. Use board as a sling.
5. Carefully transfer the victim on a stretcher.
6. Call a doctor.

5.1.12 Basic fire awareness

Fire is a chemical reaction that requires three elements to be present for the reaction to take place and continue.

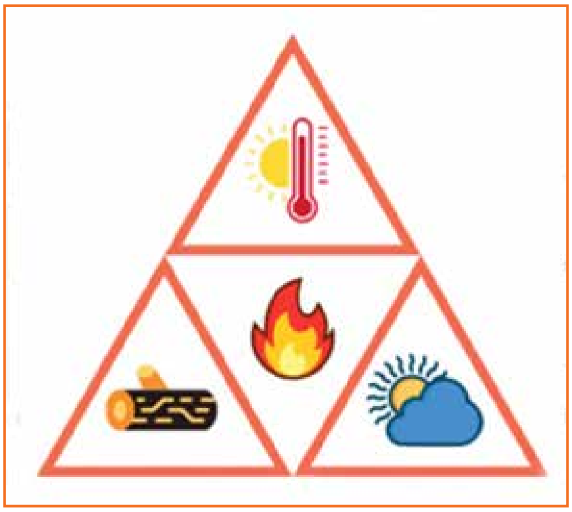


Fig: 5.1.10 Basic cause for fire

1. **Heat:** A heat source is responsible for the initial ignition of fire, and is also needed to maintain the fire and enable it to spread. Heat allows fire to spread by drying out and preheating nearby fuel and warming surrounding air.
2. **Fuel:** Fuel is any kind of combustible material. It's characterized by its moisture content, size, shape, quantity and the arrangement in which it is spread over the landscape. The moisture content determines how easily it will burn.
3. **Oxygen:** Air contains about 21 per cent oxygen, and most fires require at least 16 percent oxygen content to burn. Oxygen supports the chemical processes that occur during fire. When fuel burns, it reacts with oxygen from the surrounding air, releasing heat and generating combustion products (gases, smoke, embers, etc.). This process is known as oxidation.

These three elements typically are referred to as the **"fire triangle."** Fire is the result of the reaction between the fuel and oxygen in the air.

Causes of fire

- **Electrical:** e.g. overloading of circuits, faulty old or bad connections causing sparks or generating a heat source, poor maintenance, lack of ventilation and cooling, static electricity etc.
- **Heating appliances:** for example clothing left on boilers to dry, no sparks guards on open fires or stoves, left unattended while cooling, sited close to combustible materials, faulty temperature control etc.
- **Process dangers:** e.g. overheating of machinery, heat generated by friction, uncontrolled sparking, breakdown in cooling process, chemical reaction, poor quality ventilation and temperature control etc.
- **Flammable dusts:** e.g. poor extraction, process proximity to heat or spark source, no containment system, no monitoring or measuring system etc.
- **Carelessness:** For example smoking, inadequate precautions while welding, drilling or cutting, horseplay or interference with safety equipment, removal of guards etc.
- **Bad housekeeping:** For example lack of maintenance of work area and equipment, oil/fuel leaks and spillage's ignored, overflowing bins and waste baskets, no safe procedures for disposing of combustible waste etc.
- **Spontaneous combustion:** For example chemicals not stored at correct temperature, chemicals mixed incorrectly, combustible materials or waste left unattended etc.
- Poor judgment and human error.
- Failure to follow instructions.
- Misuse of faulty electrical equipment.
- **Electrical appliances:** Many fire started by electrical appliances are associated with lamps and heat developed by filament. Portable lamps are a frequent source of trouble the common causes as follows.

    i. Lead wires damaged.

    ii. Lamp taken in to atmosphere which has explosive dust, gas or vapour.

    iii. Bulb loose in socket.

    iv. Bulb easily broken (take care properly).

Classification of fire

Before we move forward and study about fire prevention and the safety equipment required for the same, we need to understand the different types of fire. This information is extremely important as it can help you choose the appropriate means to extinguish the fire.

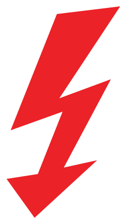
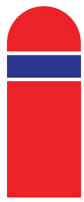
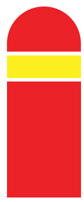
Classes of Fire	
Class A Fires are related to solid materials (wood, paper, cloth, trash, rubber and plastics, charcoal, etc.)	
Class B Fires are related to flammable liquids (paint, diesel, gasoline, petroleum oil, and pain).	
Class C Fires are related to flammable gases (energized electrical equipment like motors, appliances, transformers, propane, and methane). Electrical equipment such as appliances, wiring, and breaker panels, etc. These categories of fires become Class A, B, and D fires when the electrical equipment that initiated the fire is no longer receiving electricity).	
Class D Fires are related to flammable metals (combustible material like aluminium, sodium, potassium, magnesium). These fires burn at extremely high temperatures and require special suppression agents.	
Class E Fires are related to electrically energized objects, wiring, and electrical appliances. These fires are caused because of faulty heaters or electrical appliances overheating.	
Class K Fires related to cooking oil and greases like vegetable fat and animal fat.	

Table: 5.1.2 Classification of fire

Fire extinguisher

Fire extinguishers are designed to tackle specific types of fire. There are five different classes of fire and several different types of fire extinguishers.

Types of fire extinguisher	Identification		
	Use	Fire class	Colour code
Water extinguisher 	• Water removes heat and extinguishes the fire. • Water must not be used on fires involving live electrical equipment as it can cause electrocution. • Water must not be used on metal fires.	Class a fire.	Signal red. 
Dry chemical powder (DCP) extinguisher 	• DCP extinguishers put out fire by coating the fuel surface with chemical powder. • This separates the fuel from the oxygen in the air and prevents vapour formation.	Class b & c fire.	Red with a blue panel above the operating instructions. 
Foam type extinguisher 	• The extinguishing agent is aqueous film forming concentrate in water which forms air foams when discharged through an aspirating nozzle. • It has a blanketing effect excluding oxygen from the surface of the fuel as it spreads on the fuel. • Prevents vapour formation from the surface of the burning liquid.	Class a & b fire.	Red with a cream panel above the operating instructions. 

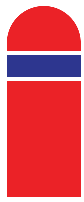
Types of fire extinguisher	Identification		
	Use	Fire class	Colour code
Carbon dioxide extinguisher 	• Co2 extinguish the fire by displacing oxygen in the surrounding air. • Its principal advantage is that it does not leave any residue. • Can be used on electrical/ electronic equipment. • Co2 is not suitable for fires involving metals.	Class b & c fire.	Red with a black panel above the operating instructions. 
Special dry powder	• Special extinguishing agents are used for extinguishing metallic fires. • Dry powders extinguish the fire by forming a crust on metal surface excluding air and also absorb heat from the metal surface.	Class d fire	Red with a blue panel above the operating instructions. 

Table: 5.1.3 Classes of fire extinguisher

Correct use of a fire extinguisher

The method of using a fire extinguisher is to follow P.A.S.S. PASS is the acronym for, pull the pin (p), aim (a), squeeze (s) and sweep (s).

1. **Pull the pin:** to use an extinguisher in a proper way, the first step is to pull the handle's pin.
2. **Aim:** the next step is to aim the extinguisher's nozzle. The direction should be towards the fire's base. This is because the sprayed foam at the top will diminish or extinguish only the fire at the top. This will not serve the purpose for which the extinguisher is used. The burned down flame may spring up to life if it gets enough oxygen or any combustible material.
3. **Squeeze:** then, in an extremely controlled manner, you need to release the agent. This can be done by squeezing the trigger.
4. **Sweep:** if you see in the second step, you already read that you should direct the nozzle at the fire's base. You will sweep the extinguisher's nozzle from left to right. Continue with this process until you put out the fire. You need to act fast as most extinguishers' discharge time is nearly 10-20 seconds.

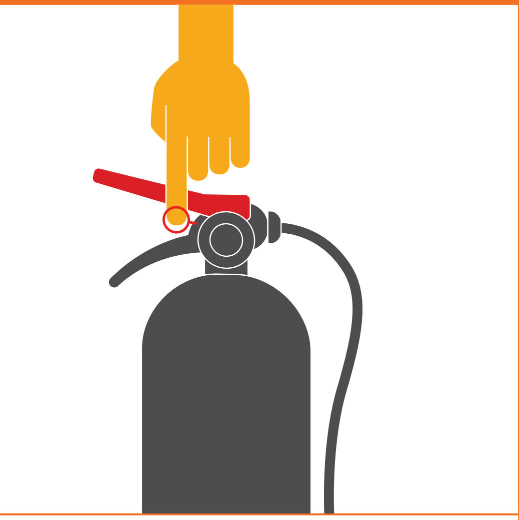
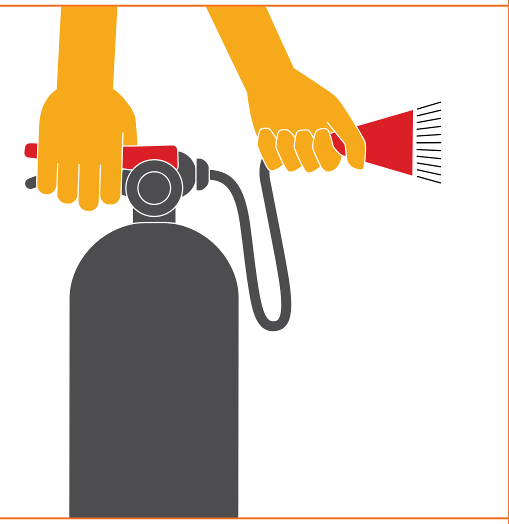
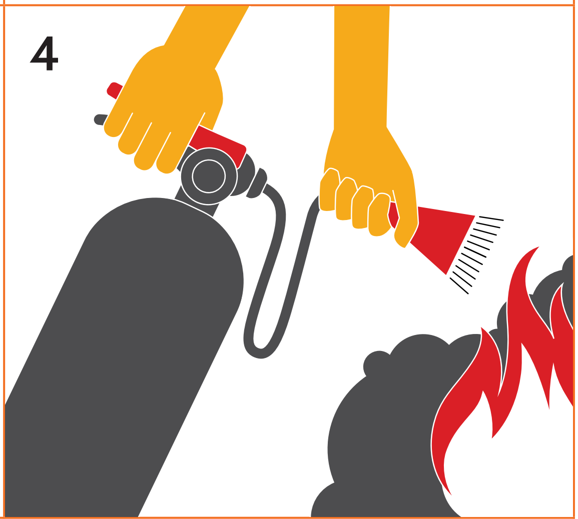
PASS Technique	
1 	2 
Pull out the safety pin as instructed on the label	**Aim the nozzle at the base of the fire**
3 	4 
Squeeze the lever	**Sweep the fire using the extinguisher's discharge**

Table: 5.1.4 Fire extinguisher PASS method

How to deal with fire

If the house has got fire, you need to take following steps:

- If the fire is very small and can be handled, you should deal with it yourself. Otherwise, you should come out of the house with other family members.
- Call the fire brigade and also the neighbours for help.
- If your clothes got fire, lie down on the floor and roll around so that the flames may smooth.
- If you are trapped in a fire in a room, bent down on your knees and try not to inhale the smoke as much as possible.
- You should crawl toward the exit as soon as you can.

- You can use the fire extinguisher on the small fire, but you should get yourself trained on it.

Methods of starving fire

On discovery of a fire, everything possible should be done to starve the fire by removing the oxygen and combustible material. The prevention procedure is as follows.

- Close all the doors and windows;
- Cover small fires with a blanket or other suitable objects;
- Cool the fire down;
- Remove combustibles;
- Switch off all electricity main switch; and
- If available, use the appropriate extinguishers.

Remove bystanders from the danger area to a safe place. Keep an access route open for the fire brigade or emergency services and look out for looters as people may take advantage of the confusion caused by the fire to steal valuables.

Fire emergency procedures (do's & don'ts)

The general principles (do's and don'ts) when conducting basic fire-fighting is as follows.

Do's

- Ensure the back-up assistance is available before tackling a fire;
- Ensure that an escape route is available before tackling the fire;
- Follow instructions on the extinguisher's label;
- Apply the extinguisher medium to the base of the flames and move the nozzle in a rapid side-to-side action;
- Drive the flames away from you;
- For vertical fires, start at the base of the flames and move upwards;
- If the fire is outdoors, approach the fire from the windward side;
- When approaching the fire, adopt a crouching position that provides protection against heat and smoke;
- Keep alert for any changes in the fire pattern;
- When tackling a fire involving electrical equipment, isolate the power as soon as possible to prevent re-ignition; and
- Ensure that the fire has been completely extinguished and no spark remains.

Don'ts

- Do not place yourself at risk;
- If the fire is too big, evacuate the area immediately;
- Never tilt or invert any extinguisher during operation unless it is the turnover type;
- When extinguishing the fire of a flammable spillage, never walk on the liquid spillage. This can

prevent injuries in the event of the names flashing back;

- When tackling flammable liquid fires using a controllable discharge type extinguisher, spray the medium until the fire is completely extinguished; and
- After the fire has been extinguished, back off slowly and never turn your back on it.

Fire evacuation steps

The sequence of an evacuation situation is:

- Detection.
- Decision.
- Alarm.
- Reaction.
- The movement to an area of refuge or an assembly station/ area.
- Transportation.

Rescue techniques during fire hazard

(A) Responding to fire

- The fire alarm system must be initiated, and an alert must be raised.
- A safe evacuation path must be identified before dealing with the fire.
- The appropriate class of fire extinguisher must be chosen.
- The P.A.S.S. technique must be adopted for extinguishing the fire.
- Immediate evacuation must be initiated if the extinguisher is exhausted and the fire still exists.
- Call security or local emergency services.
- Summon the fire fighting services at the earliest.
- Stay as far as possible from smoke, because the smoke may comprise toxic gases.
- Cover your mouth and nose with a damp cloth. Place a damp cloth above the person too and ensure that the person does not inhale toxic gases.
- Look out for the nearest emergency exit routes and call out for people, who you can take along with you.
- While opening a door, first touch the door with the back of your palm.
- Wrap the person with a blanket to protect him/ her from fire.
- Start moving out of the building carefully as you have to carry a person with yourself.
- Always use a staircase and not the elevator.
- Do not rush.
- As you move out of the building, gather people, whoever you come across.
- Always move downstairs and avoid returning to the burning premises, until the fire-fighters arrive.

(B) Initiate evacuation

- Stop your work immediately but do not panic.

- Gather and carry only the most important items like a cell phone before leaving with the person.
- Leave the house via the nearest door bearing an **"exit"** sign.
- Report to the person's parents over the telephone if they are not present.
- Call 101 for fire emergency or 108 for other natural disaster help.
- Incorporate first aid treatment to the person, if needed.

(C) Emergency evacuation process

- On hearing an evacuation alarm or instruction of any people inside or outside the house regarding fire, immediately cease all activity and secure personal valuables.
- Assist any person in immediate danger, but only if safe to do so.
- If practical, and only if safe to do so, secure any activity or process that may become hazardous or suffer damage if left unattended as a consequence of evacuation.
- Act in accordance with directions given by emergency control personnel and evacuate the building immediately.
- Assist with the general evacuation if directed to do so by emergency control personnel.
- Assist with the evacuation of disabled occupants.
- In a fire, do not use a lift to evacuate a building.
- Move calmly to the nominated evacuation assembly area and do not leave the evacuation assembly area until the all clear has been given.
- Follow the instructions of relevant emergency services personnel and campus emergency control personnel.

5.1.13 First aid

First aid is the first assistance or treatment given to a casualty or a sick person for any injury or sudden illness before the arrival of an ambulance, the arrival of a qualified paramedical or medical person or before arriving at a facility that can provide professional medical care.

Aims of first aid

The aims of first aid are:

- To preserve life,
- To prevent the worsening of one's medical condition,
- To promote recovery, and
- To help to ensure safe transportation to the nearest healthcare facility.

Role of first aider: Remember pact

P - Protect
A - Assess

C - Care	
T - Transport-Triage	

(A) Vital signs

Vital signs are measurements of the body's basic functions. Normal vital signs change with age, sex, weight, exercise tolerance, and overall health. The four main vital signs that are usually monitored are given as follows.

Vital Signs	Good	Poor
Heart Rate	60-100 beats per minute	Less than 60 or greater than 100 beats per minute
Respirations	14-16 breaths per minute	Less than 14 breaths per minute
Skin	Warm, pink and dry	Cool, pale and moist
Consciousness	Alert and orientated	Drowsy or unconscious

Table: 5.1.5 Vital sign

(B) Four a's

Awareness	Assessment	Action	After care
• Observe • Stop to Help	• Assess what is required to be done. • Ask yourself, 'Can I do it?'	• Do what you can. • Call for expert medical help. • Take care of your and the bystander's safety.	• Once you have assisted the victim, stay with him/her till expert care arrives.

Table: 5.1.6 Four a's

(C) Degrees of burns

1st Degree Burn	2nd Degree Burn	3rd Degree Burn	4th Degree Burn
Will recover by it-self in a few days. Action Required: Place under running water. 	Serious but recovers in a few weeks. Action Required: Place clean wet cloth over the burnt area. 	Very Serious and will require skin grafting. Action Required: Place a clean dry cloth over the burnt area. 	Extremely Serious and requires many years with repeated plastic surgery and skin grafting, is life threatening. Action Required: Leave open and prevent infection. 

Table: 5.1.7 Burn classification

(D) First aid techniques for common injuries

Some common techniques to first aid common injuries.

Injury	Symptom	Do's	Don'ts
Fracture	• Pain • Swelling • Visible bone	• Immobilise the affected part. • Stabilise the affected part. • Use a cloth as a sling. • Use board as a sling. • Carefully Transfer the victim on a stretcher.	• Do not move the affected part. • Do not wash or probe the injured area.

Burns (see Degrees of Burn table)	• Redness of skin. • Blistered skin. • Injury marks. • Headache/seizures.	• In case of electrical burn, cut-off the power supply. • In case of fire, put out fire with blanket/coat. • Use water to douse the flames. • Remove any jewellery from the affected area. • Wash the burn with water. 	• Do not pull off any clothing stuck to the burnt skin. • Do not place ice on the burn. • Do not use cotton to cover the burn.
Bleeding	• Bruises. • Visible blood loss from body. • Coughing blood. • Wound/ Injury marks. • Unconsciousness due to blood loss. • Dizziness. • Pale skin.	• Check victim's breathing. • Elevate the wound above heart level. • Apply direct pressure to the wound with a clean cloth or hands. • Remove any visible objects from the wounds. • Apply bandage once the bleeding stops.	• Do not clean the wound from out to in direction. • Do not apply too much pressure (not more than 15 mins). • Do not give water to the victim.

Table: 5.1.8 First aid techniques for common injuries

5.1.14 Cardiopulmonary resuscitation (CPR)

Cardiopulmonary resuscitation (CPR) is a lifesaving technique. It aims to keep blood and oxygen flowing through the body when a person's heart and breathing have stopped. CPR can be performed by any trained person. It involves external chest compressions and rescue breathing. CPR performed within the first six minutes of the heart stopping can keep someone alive until medical help arrives.

Fundamentally these are referred to as abc of life. The process is always referred to perform in an emergency:

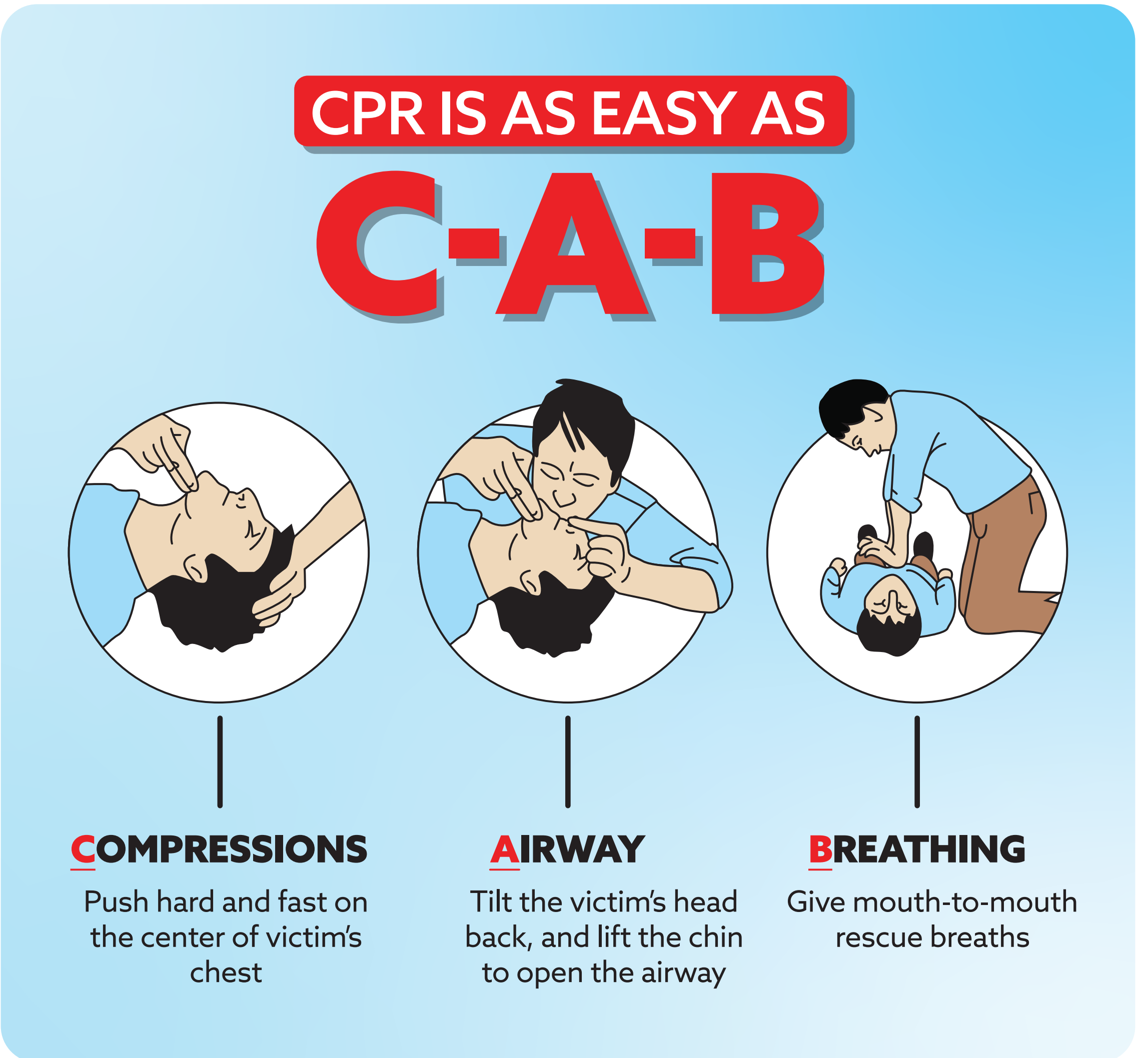


Fig: 5.1.11 CPR Process

Performing hands-only CPR

If a person is not breathing, his or her heartbeat will stop. These CPR steps (chest compressions and rescue breaths) will help circulation and get oxygen into the body.

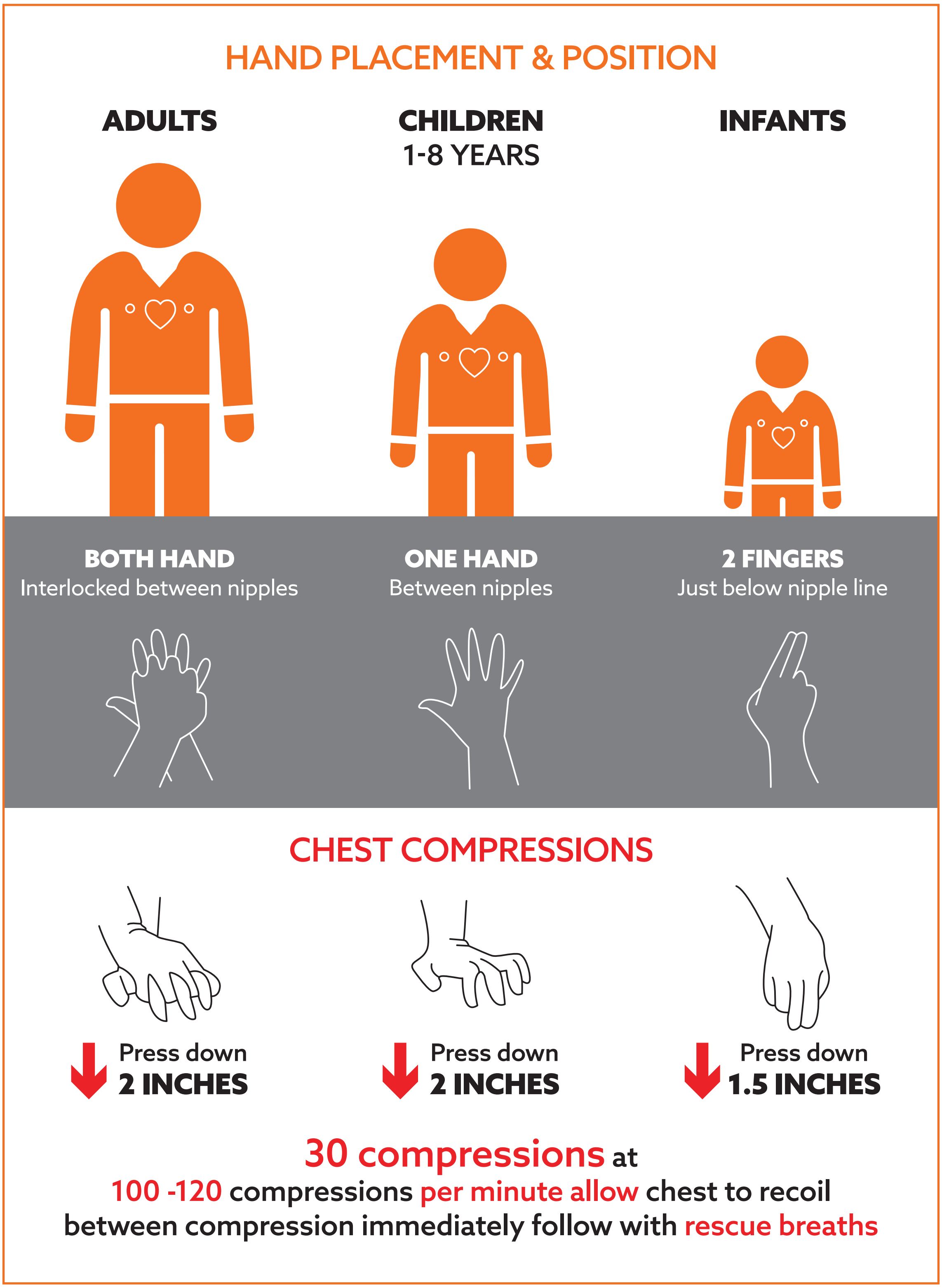


Fig: 5.1.12 Performing CPR Steps

Step 1: Position your hand Make sure the victim is lying on his back on a firm surface. Kneel beside him and place the heel of your hand on the centre of the chest.	
Step 2: Interlock fingers Keeping your arms straight, cover the first hand with the heel of your other hand and interlock the fingers of both hands together. Keep your fingers raised so they do not touch the Victim's chest or rib cage.	
Step 3: Give chest compressions Lean forward so that your shoulders are directly over the victim's chest and press down on the chest about two inches. Release the pressure, but not your hands, and let the chest come back up. Repeat to give 30 compressions at a rate of 100 compressions per minute.	
Step 4: Open the airway Move to the victim's head. Tilt his head and lift his chin to open the airway again. Let his mouth fall open slightly.	
Step 5: Give rescue breaths Pinch the nostrils closed with the hand that was on the forehead and support the victim's chin with your other hand. Take a normal breath, put your mouth over the victim's, and blow until you can see his chest rise.	
Step 6: Watch chest fall Remove your mouth from the victim's and look along the chest, watching the chest fall. Repeat steps five and six once.	
Step 7: Repeat chest compressions and rescue breaths Place your hands on the chest again and repeat the cycle of 30 chest compressions, followed by two rescue breaths. Continue the cycle.	

Table: 2.2.1 Performing CPR steps

5.1.15 Accident/incident report forms

There are many kinds of accident/incident report forms but all do the same job – they all include the findings of the investigation and determine the causes of the incident. They also provide recommendations to prevent further occurrences. There are also various computer programs which have been developed to record and analyse data. Whatever the format, they all state.

- **What happened:** The injuries/losses/costs.
- **How it happened:** The event itself.
- **Why it happened:** The causes, root, underlying and immediate.
- **Recommendations:** Any action to be taken to remedy the situation and prevent any recurrences.

The use of standardized report forms ensures that the investigation process is correctly adhered to and that information can be reported back to management. Follow- up actions can easily be taken following appropriate recommendations within the report. Standardized report forms can also act as a checklist.

An efficient recording system will:

- Ensure the information is correctly and accurately presented.
- Allow the data to be analysed easily in order to discover common causes or trends.
- Ensure data which may be required for future reference is included.
- Identify issues which may help prevent any recurrence of the accident.

Report forms should be reviewed on a regular basis to ensure that any recommendations have been implemented.

Summary

- As defined by who, health is a "state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity''.
- Safety is the state of being 'safe', the condition of being protected from harm or other non-desirable outcomes.
- Workers in oil and gas industry are generally susceptible to certain safety and injury hazards such as, motor vehicle accident, contact injuries, fire and explosions, slip, trips and falls etc.
- Workers in oil and gas industry are generally susceptible to chemical hazards, physical hazards, biological hazards, ergonomic hazards, psychosocial hazards.
- It is important that driver, drive shaft, are secured from inadvertent movement before anyone works on the pump.
- It is important to ensure that the steam - and the associated steam condensate system - are properly isolated.
- A systematized approach PDCA should be used for managing occupational safety and health hazards.
- Risk management includes, identifying the risks, evaluating and prioritizing the risks, implementing

preventive/protective measures to control the risk.

- Job safety analysis is a process of systematically evaluating certain jobs, tasks, processes or procedures and eliminating or reducing the risks or hazards in order to protect workers from injury or illness.
- Personal protective equipment (PPE) is a clothing or equipment worn by workers to protect them from various hazards.
- Fire extinguishers are designed to tackle specific types of fire.
- There are five different classes of fire, class a, b, c, d, e, k.
- There are different types of fire extinguishers, water extinguisher, dry chemical powder, foam type extinguisher, carbon dioxide extinguisher, special dry powder.
- The fire extinguishers are used by following PASS technique.
- First aid is the first assistance or treatment given to a casualty or a sick person for any injury or sudden illness before the arrival of an ambulance.
- Cardiopulmonary resuscitation (CPR) is a lifesaving technique. It aims to keep blood and oxygen flowing through the body when a person's heart and breathing have stopped.

Exercise

1. **A .... examines the hazardous conditions at a workplace to identify risks and implement measures to prevent or reduce the risks.**
   a) Risk assessment b) Ergonomics
   c) Air quality d) Visual Inspection
2. **These are the clothing or equipment worn by workers to protect them from fire, exposure to toxic chemicals and direct impact.**
   a) Risk Identification b) Personal Protective Equipment (PPE)
   c) Proximity suits d) Administrative controls
3. **The method of using a fire extinguisher is to follow P.A.S.S. PASS is the acronym for, Pull the Pin (P), Aim (A), Squeeze (S) and ....**
   a) Swing b) Sweep
   c) Swipe d) Send
4. **These are the type of burns which are very serious and require skin grafting.**
   a) 1st degree burn b) 2nd degree burn
   c) 3rd degree burn d) 4th degree burn
5. **What does CPR stand for?**
   a) Cardiac personal resuscitation b) Caring personal rescue
   c) Cardiopulmonary rescue d) Cardiopulmonary resuscitation

6. **These are the signs which mean "You must not" or "Do not do. . .," or "Stop."**
   a) Prohibition signs b) Mandatory action signs
   c) Warning signs d) Fire safety signs

7. **This occurs with the failure of the circulatory system due to which insufficient oxygen reaches the tissues.**
   a) Fractures b) Shock
   c) Muscle cramps d) Dislocation

8. **These are the class of fire that are related to solid materials.**
   a) Class B b) Class C
   c) Class D d) Class A

9. **Which of the following is strictly prohibited in fire emergency procedures?**
   a) Apply the extinguisher medium to the base of the flames
   b) Do not drive the flames away from you
   c) Follow instructions on the extinguisher's label
   d) Ensure that the fire has been completely extinguished

10. **In order to be a first aider one must remember PACT, what does P stand for in PACT?**
   a) Prevent b) Protect
   c) Prioritize d) Process

Scan the QR codes or click on the link to watch the related videos

https://youtu.be/apwK7Y362qU

Know what to do during a fire

Scan the QR codes or click on the link to watch the related videos

https://youtu.be/QEB7wE-YFXg

Personal protective equipment

Scan the QR codes or click on the link to watch the related videos

https://youtu.be/2V2FFQUfxj0

Types of safety signs and symbols

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https://youtu.be/xnZZruGjKBA

Classes of fire

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https://youtu.be/aU1P7-Cn72s

Types of fire and fire extinguishers

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Fire extinguishing agents

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https://youtu.be/XmPnXzQVLQg

Clean agent fire suppression system

Scan the QR codes or click on the link to watch the related videos

https://youtu.be/9igRiyURobE

How to use a fire extinguisher

6. Annexure

Sl No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
1	Module 1	Unit 1.1 - Introduction to hydrocarbon sector	1.2.1 What does a pipeline maintenance technician do?	13	https://youtu.be/W-PooTpdcyw	The People Behind The Pipeline
2	Module 2	Unit 2.1 - Introduction to crude oil	2.1.1 What Is Crude Oil?	69	https://youtu.be/6ozmKhahk8M	Fundamentals of upstream, midstream, and downstream
3	Module 2	Unit 2.1 - Introduction to crude oil	2.1.1 The process of crude oil refining	69	https://youtu.be/cXnHOOTCrKY	Crude-oil distillation in a refinery
4	Module 2	Unit 2.1 - Introduction to crude oil	2.1.2 Natural Gas Processing	69	https://youtu.be/QgtSoEJD9HE	Turning natrual gas into liquid
5	Module 2	Unit 2.1 - Introduction to crude oil	2.1.2 Natural Gas Processing	69	https://youtu.be/PenuYdMm3Wg	Natural Gas 101: Natural Gas Transportation

Sl No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
6	Module 2	Unit 2.1 - Introduction to crude oil	2.1.3 Pipelines	70	https://youtu.be/Gap_IhBIrGI	How are pipelines constructed?
7	Module 2	Unit 2.2 - Equipment and machines	2.2.1 Work Permit System	70	https://youtu.be/_aNY6mV6ggE	Work permit system | Types of work permit | validity of work permit
8	Module 2	Unit 2.2 - Equipment and machines	2.2.23 Repair Techniques	70	https://youtu.be/-On1mpWlHpk	Pipeline leak repair clamps
9	Module 3	Unit 3.1 - Carry out repair and preventive maintenance	3.1 Repair and Preventive Maintenance	90	https://youtu.be/9VR_gJ1FAyk	Reliability Centred Maintenance | RCM Explained
10	Module 3	Unit 3.1 - Carry out repair and preventive maintenance	3.1.3 Pressure Tests	90	https://youtu.be/lRFWeTRAcCU	Pipeline safety

Sl No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
11	Module 3	Unit 3.2 - Testing of equipment & machine after repair	3.2.1 What is 5s?	90	https://youtu.be/CcbogALFNX0	Toyota Material Handling | Why 5s
12	Module 4	Unit 4.1 - Working effectively in a team	4.1.1 Effective Communication	90	https://youtu.be/EDMY39JE1sY	5 steps to manage conflict between team mem-bers
13	Module 4	Unit 4.1 - Working effectively in a team	4.1.1 Achieve Goals in the Workplace	102	https://youtu.be/9MO1aY1xC80	Motivation - leader and teamwork!
14	Module 4	Unit 4.1 - Working effectively in a team	4.1.4 Working Effectively in a Team	102	https://youtu.be/6fbE52YDEjU	Team work can make the dream work
15	Module 4	Unit 4.1 - Working effectively in a team	4.1.4 Work Effec-tively in a Team	102	https://youtu.be/H_vOfqIpD60	Why team building is important

Sl No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
16	Module 4	Unit 4.1 - Working effectively in a team	4.1.6 Work Effectively in a Team	102	https://youtu.be/WTa4wvFVX_Y	How to manage conflict in a team
17	Module 4	Unit 4.1 - Working effectively in a team	4.1.6 Work Effectively in a Team	102	https://youtu.be/fUXdrl9ch_Q	Good Teamwork and Bad Teamwork
18	Module 5	Unit 5.1 - Maintain a safe working environment	5.1.9 Rescue techniques applied during a fire hazard	139	https://youtu.be/apwK7Y362qU	Know what to do during a fire
19	Module 5	Unit 5.1 - Maintain a safe working environment	5.1.9 Use of personal protective equipments	139	https://youtu.be/QEB7wE-YFXg	Personal protective equipment
20	Module 5	Unit 5.1 - Maintain a safe working environment	5.1.10 Various types of safety signs and what they mean	139	https://youtu.be/2V2FFQUfxj0	Types of safety signs and symbols

Sl No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
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22	Module 5	Unit 5.1 - Maintain a safe working environment	5.1.12 Techniques of using the different fire extinguishers	140	https://youtu.be/aU1P7-Cn72s	Types of fire and fire extinguishers
23	Module 5	Unit 5.1 - Maintain a safe working environment	5.1.12 Techniques of using the different fire extinguishers	140	https://youtu.be/3nakKzM66hk	Fire extinguishing agents
24	Module 5	Unit 5.1 - Maintain a safe working environment	5.1.12 Techniques of using the different fire extinguishers	140	https://youtu.be/XmPnXzQVLQg	Clean agent fire suppression system
25	Module 5	Unit 5.1 - Maintain a safe working environment	5.1.12 Different methods of extinguishing fire	140	https://youtu.be/9igRiyURobE	How to use a fire extinguisher

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