Chapter 1 : Industrial Hazards and Safety Precautions

INTRODUCTION

➢ Hazard is a term associated with a substance that is likelihood to cause an injury in a given environment or situation.

➢ Industrial hazard may be defined as any condition produced by industries that may cause injury or death to personnel or loss of product or property.

• Safety in simple terms means freedom from the occurrence of risk or injury or loss.

• Industrial safety refers to the protection of workers from the danger of industrial accidents.

TYPES OF HAZARDS

1. Biological hazards
2. Chemical hazards
3. Mechanical hazards
4. Physical hazards
5. Electrical hazards
6. Fire hazards
7. Dust hazards

1. MECHANICAL HAZARDS

A mechanical hazard is involving a machine or process. Motor vehicles and air bags pose mechanical hazards. Compressed gases or liquids can also be considered a mechanical hazard.

SOURCE OF MECHANICAL HAZARDS

➢ It occurs when a machine is malfunctioning.

➢ Machines may run either manually or automatically.

➢ A few machines are cutting, shearing, crushing, breaking.

➢ Most injuries occur when the machine needs human intervention repeatedly for its proper functioning.

➢ The machines are driven by a suitable power supply (electricity or steam).

PREVENTION OF MECHANICAL HAZARDS

Requirements for Safeguards

Safeguards must meet these minimum requirements:

Prevent contact:

The safeguard must prevent hands, arms, or any part of a worker's body from making contact with dangerous moving parts.

Secure:

Workers should not be able to easily remove with the safeguard. Guards and safety devices should be made of durable material that will withstand the conditions of normal use.

Protect from falling objects:

The safeguard should ensure that no objects can fall into moving parts. A small tool which is dropped into a cycling machine could easily become a projectile that could strike and injure someone.

Create no new hazards:

The edges of guards, for instance, should be rolled or rounded in such a way that they eliminate sharp edges to prevent unwanted injuries.

Create no interference: Proper safeguarding can actually enhance efficiency, since workers will not be afraid of injuries then.

Allow safe lubrication:

If possible, one should be able to lubricate the machine without removing the safeguards. Locating oil reservoirs outside of the guard, with a line leading to the lubrication point, will reduce the need for the operator or maintenance worker to enter the hazardous area.

2. ELECTRICAL HAZARDS

Shock is one of the common electrical hazards. It occurs when the electric current passes through the body. This is possible when human is in contact with a conductor carrying a current and simultaneously in contact with the ground. This is referred to as short circuit.

SOURCE OF ELECTRICAL HAZARDS

➢ Different sources of electrical hazards are short circuit, electrostatic hazards and explosive materials.

➢ A worker will receive a shock when he/she:

Touches two wires at different voltages at the same time.

➢ Touches the phase standing on the ground

➢ Touches the phase having wet cloth and high humidity.

➢ Receive a shock from electrical components those are not grounded properly.

➢ Touching another person receiving an electrical shock.

Prevention of electric hazards

All workplaces have an electrical safety policy created by authority.

Electrical Safety Policy

The following items should be included in the electrical safety policy:

➢ Power equipment should be plugged into wall receptacles with power switches in the off position.

➢ Electrical equipment should be unplugged by grasping the plug and pulling. Never pull or jerk the cord to unplug the equipment.

➢ Frayed, cracked or exposed wiring on equipment cords must be corrected. Also check for defective cord clamps at locations where the power cord enters the equipment or the attachment plug.

➢ Temporary or permanent storage of materials must not be allowed within 3 feet of electrical equipment.

➢ Any electrical equipment causing shocks or which has high leakage potential must be tagged with a DANGER—DO NOT USE label or equivalent.

PREVENTION OF ELECTRICAL HAZARDS

Responsibilities of individual employee

➢ Training and Education: Many accidents are caused due to lack knowledge of the equipment or its operation. So, employees should be trained in electrical safety work practices and equipment operation.

➢ Hazardous Condition Reporting: Employees should always report unsafe equipment, conditions or procedures. Under no condition should defective electrical equipment causing electrical shock be used immediately.

➢ Work Practices: Employees are responsible for following their employer's safe work practices, procedures and policy.

➢ Housekeeping: Good housekeeping requires all employees to observe activities that could cause electrical shock hazards. For example, using electrical equipment that is not properly grounded in areas that have water on the floor can create shock hazards. Cleaning tools and electrical equipment with solvents can create health and physical safety problems.

3. CHEMICAL HAZARDS

Source of Chemical Hazards

Solvents used in extraction plants, purification of synthetic drugs and in chemical analysis may produce vapours.

1. This vapours or gases may produce:

➢ Breathing problem and suffocation to worker.

➢ Irritation or burn to eye or skin of the worker.

➢ Explosion in the workplace.

➢ General anaesthesia or death e.g. chloroform and ether vapour.

2. Liquid chemicals if spilled on workers may produce

➢ Dehydration by strong dehydrating agents e.g. concentrated sulfuric acid.

➢ Burning by strong acid or alkalis.

➢ Oxidation by strong oxidising agents.

3. Dusts of chemicals produced from different equipment may produce

➢ Dermatitis or dust allergies to the workers.

➢ Skin and eye irritations.

➢ Resistance to certain antibiotics e.g. resistant to chloroform if the same worker is exposed to it regularly. Some dust may be carcinogenic (producing cancers).

Safety Measures

➢ Before starting work with a chemical a "chemical hazard pocket guide" should be consulted for necessary information about the chemical. It will give the type of reaction the chemical may produce, its inflammability, carcinogenicity, prevention and treatment procedures etc.

➢ No eating, drinking, or smoking where chemicals are used.

➢ Skin should be covered with protective clothing.

➢ Clothing should be removed immediately it gets wet or contaminated with a chemical.

➢ Eyes or skins should be washed with plenty of water after an accident.

➢ Face mask may be used in toxic dust or gases.

➢ Workers working in antibiotic related products must be changed routinely so that an an individual is not exposed to a certain antibiotic for a long period of time.

➢ Whenever a dust allergy or respiratory problem precipitates the worker should immediately be removed from the workplace and put under proper healthcare.

➢ In case of inflammable gas or solvent leakage the exhaust fans should be started and all the source of fire should be extinguished

4. DUST HAZARDS

Dust Hazards Source of Dust Hazards

➢ Grinding or milling of drugs, excipients, or herbal products.

➢ During weighing dusts may float on air.

➢ During powder mixing dusts may be generated.

➢ During coating operation dusts are generated.

➢ During capsule filling and tablet punching operation dusts may be generated.

Prevention of Dust Hazards

Filtration

Air is sucked through a suitable filter medium (like paper, wool, cotton-wool and nylon). Filter bags can be attached with machines where dust is produced.

Inertial separator

In cyclone separator the air is circulated at high speed in a spiral manner. Due to centrifugal force the dust particles are thrown outward and the particles are collected at the bottom and the clean air comes out through the top.

Electrostatic separator

It consists of metal tubes through which a conductor wire is passed. Several thousand volts DC current is applied on the metal wire. When air is passed through the pipes the dust particles becomes charged and precipitates on the inner wall of the tube and clean air passes out. Periodically the dust is collected.

5. FIRE HAZARDS

Source of Fire Hazards
Types of fire Class
➢ A Fires
These are fires in ordinary combustible materials such as wood, cloth, paper etc. those produce glowing embers.
➢ Class B
Fires These are fires of flammable petroleum products, liquids, gases and greases etc.
➢ Class C
Fires These fires involve energised electrical equipment.
➢ Class D
Fires These are fires in combustible metals.
PREVENTION OF FIRE HAZARDS
Fire Extinguishers
Fire extinguishing agents work by:
➢ removal of fuel e.g. blanketing with foam or interposing a layer of gas between the fuel and the flames.

➢ by removal of oxygen e.g. by dilution with inert gases or vapours.
➢ by removal of heat by cooling with water or other extinguishing agents Water based fire extinguishers They produce CO_2 by reaction with acid and carbonates, or CO_2 is kept under pressure.
E.g. Portable fire extinguisher, Soda-Ash Extinguisher, Antifreeze Extinguisher. Water based foams Two types of foams are available. Chemical foams and Mechanical foams. Chemical foams are bubbles filled with CO_2 produced by chemical reaction in an aqueous solution mixed with a foaming agent. The reacting chemicals are usually of sodium carbonate and ammonium sulphate. Mechanical foams are bubbles filled with air. Foams forms barrier and prevents contact between fuel and air.
Dry chemicals
These are finely divided solid particles usually discharged through a hose pipe. Usually they contain sodium bicarbonate, potassium bicarbonate and ammonium sulphate.
❖ INDUSTRIAL DERMATITIS
Dermatitis is an inflammation of the skin. The term dermatitis is synonymous with eczema.
The skin becomes red, itchy, and can be blistered.
The skin becomes hard, thickened and cracked. Many people suffer from skin conditions. Most of these are not work related. In some instances, these started during childhood. Dermatitis is the main work- related skin disease.
An important clue for diagnosis is the site of the area affected. If it is the hands, contact dermatitis should always be suspected. The next question is whether the ‘contact’ arises from work or outside work.

A work-related cause is suggested if:
• The rash is mainly on the hands and exposed skin
• The condition improves away from work and relapses on return
• More than one person is affected in same work area or handling same materials
The following suggest a non-occupational cause:
• there is a history of childhood/ endogenous eczema
• there is major involvement of the body trunk or covered area of skin
What is contact irritant dermatitis?
In contact irritant dermatitis the substance that damages the skin is known as the irritant. A highly irritant substance is known as corrosive. Irritant dermatitis makes up about 80% of contact dermatitis. The other 20% are allergic.

There are several ways that skin damage can be caused.
• Detergents, soaps such as in repeated hand washing or the use of solvents can remove the protective oily layer and so leave the skin exposed to damage.
• Physical damage such as friction, minor cuts for example from fibreglass and grazes can break down the protective layer and allow substances access.
• Chemicals such as acids or alkalis can burn the layer. Irritation is analogous to a chemical burn. It acts by eroding or burning the outer protective layers of the skin. Irritant contact dermatitis usually occurs only on the parts of the body in direct contact with the irritant substance e.g. hands, forearms, face.
Common irritants are wet work, cutting oils, solvents and degreasing agents which remove the skins outer oily barrier layer and allow easy penetration of hazardous substances, alkalis and acids. Wet cement coming into contact with exposed feet and hands is a particular example of a skin irritant.
What do employees need to know?
Employees are entitled to information about hazards in the workplace and those contained in the Risk Assessment. They are also entitled to information on the protective and preventive measures to be taken. Employees who are likely to work with and be exposed to substances causing dermatitis need information, instruction and supervision so that they know and understand the following;
• Label and safety data sheet for chemicals used in the workplace
• Substances which are known to cause dermatitis in the workplace
• Risk Assessment
• Proper use of control measures
• Need to report any failures in control measures
• Risks to health
• Symptoms of sensitization
• Importance of reporting symptoms at an early stage
• Role of health surveillance

ACCIDENT RECORD
An accident book is used on construction projects to record details of any accidents that occur. This is a requirement of the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations.
Details of accidents that must be recorded include:
▪ The date and time on which it occurred.
▪ The person who was injured.
▪ Any witnesses.
▪ The type and nature of the injuries sustained.
▪ The cause and full circumstances of the accident.
These details should be entered into the accident book by the injured person or a colleague as soon after the accident as possible. This forms a valuable source of evidence in the event of any legal claims, and can also be valuable for employers helping identify systems or processes that need to be changed to make them safer. For example, if it is clear from examining the accident book that a project has experienced a number of accidents involving the movement of vehicles, then the site management team can take steps to address that a particular issue.
The Health and Safety Executive (HSE) recommend that all forms of accidents are recorded in the accident book, as even small incidents can provide an warning of more severe accidents that could happen in the future. However, RIDDOR identifies the more serious types of accidents which must be reported to HSE as well as being recorded in the book. These include:
▪ Any injury that stops an employee doing their normal work for a period of 3 days or more.
▪ Major injuries such as broken arms, ribs, legs, etc.
▪ Fatalities.
▪ Disease.
▪ Dangerous instance occurring at work such as machinery breaking, scaffolding collapsing and any other appliances defecting and causing damage.
The information contained in the accident book should be kept in an accessible location on site, usually with a nominated person responsible for accident reporting. Information contained in the book should be kept confidential, and to assist with this, accident books may have removable pages. It is a legal requirement that the information in the book is stored safely for a period of three years.

Chapter 2 : Fluid Flow

❖ What is Fluid Flow?

Fluid Flow is a part of fluid mechanics and deals with fluid dynamics. Fluids such as gases and liquids in motion are called fluid flow. It involves the motion of a fluid subjected to unbalanced forces. This motion continues as long as unbalanced forces are applied. For example, if you are pouring water from a mug, the velocity of water is very high over the lip, moderately high approaching the lip, and very low at the bottom of the mug. The unbalanced force is gravity, and the flow continues as long as the water is available and the mug is tilted.
❖ Types of Fluid
1. Ideal fluid
2. Real fluid
3. Newtonian fluid
4. Non-Newtonian fluid
5. Ideal plastic fluid
6. Incompressible fluid
7. Compressible fluid
Ideal fluid: A fluid is said to be ideal when it cannot be compressed and the viscosity doesn’t fall in the category of an ideal fluid. It is an imaginary fluid which doesn’t exist in reality.
Real fluid: All the fluids are real as all the fluids possess viscosity.
Newtonian fluid: When the fluid obeys Newton’s law of viscosity, it is known as a Newtonian fluid.
Non-Newtonian fluid: When the fluid doesn’t obey Newton’s law of viscosity, it is known as Non-Newtonian fluid.
Ideal plastic fluid: When the shear stress is proportional to the velocity gradient and shear stress is more than the yield value, it is known as ideal plastic fluid.
Incompressible fluid: When the density of the fluid doesn’t change with the application of external force, it is known as an incompressible fluid.
Compressible fluid: When the density of the fluid changes with the application of external force, it is known as compressible fluid.
❖ Types of Fluid Flow
Fluid flow has all kinds of aspects — steady or unsteady, compressible or incompressible, viscous or non-viscous, and rotational or irrotational, to name a few. Some of these characteristics reflect the properties of the liquid itself, and others focus on how the fluid is moving.
Steady or Unsteady Flow: Fluid flow can be steady or unsteady, depending on the fluid’s velocity:
• Steady: In steady fluid flow, the velocity of the fluid is constant at any point.
• Unsteady: When the flow is unsteady, the fluid’s velocity can differ between any two points.
Viscous or Non-Viscous Flow: Liquid flow can be viscous or non-viscous.

Viscosity is used to measure the thickness of a fluid, and very gloppy fluids such as motor oil or shampoo are called viscous fluids.

Fluid Flow Equation

The volume of fluid replaced in a given interval of time is called the fluid flow equation.

Mass flow rate=ρAV

Where,

ρ = density

V = Velocity

A = area

Flow rate=Area × Velocity

1. Steady & Steady Flows: -

steady Flows: In which the fluid Characteristics Like velocity, pressure, density, etc. At a Point do not change with time

Unsteady Flow: In which the fluid Characteristics Like velocity, pressure or density at a point changes with respect to time.

2. Uniform & Uniform Flow

Uniform Flow: In which the velocity at a given time does not change with respect to space (length of direction of the flow) Non-Uniform Flow: - In which the velocity at any time changes with respect to space. Changing in space

3. Laminar Flow & Turbulent flows: -

Laminar Flow: In which the fluid particles move along well-defined paths or stream lines.

Turbulent flows:

• fluid moves in very irregular paths or zig – zag Way.
• velocity at a point fluctuates.

4. Compressible Flows & Incompressible Flows

Compressible Flows:

• In which the density of fluid changes from point to point.
• The density is not constant for the fluid.

Incompressible Flows:

• In which the density of the fluid changes from point to point.
• The density is constant for the fluid.

5. Rotational Flow & Irrotational Flows: -

Rotational Flow:In which the fluid particles, while flowing along streamlines, also rotate about their own axis.

Irrotational Flows: In which the fluid particles, while flowing along streamlines, do not rotate about their own axis.

6. One, Two & Three-Dimensional Flows

One Dimensional Flow: In which the flow parameter such as velocity is a function of time and one space coordinate only, is called.

Two-Dimensional Flow: In which the flow parameter such as velocity is a function of time and two rectangular space coordinates, is called.

Three-Dimensional Flow: In which the flow parameter such as velocity is a function of time and Three mutually perpendicular directions, is called.

❖ Reynolds number: Reynolds number is a dimensionless value which is applied in fluid mechanics to represent whether the fluid flow in a duct or pat a body is steady or turbulent. This value is obtained by comparing the inertial force with the viscous force. The Reynolds number is denoted by Re. Reynolds number is given by, Reynolds Number = Inertial Force / Viscous Force

The Reynolds number formula is expressed by,

Where,

ρ = density of the fluid,

V = velocity of the fluid,

μ = viscosity of fluid,

L = length or diameter of the fluid.

The Reynolds number formula can be used in the problems to calculate the Velocity (V), density (ρ), Viscosity (μ) and diameter (L) of the liquid. Flow type Reynolds Number Range Laminar regime Less than 2000 Transition regime 2300-4000 Turbulent regime Above 4000

❖ Viscosity:

Viscosity is often referred to as the thickness of a fluid. You can think of water (low viscosity) and honey (high viscosity). However, this definition can be confusing when we are looking at fluids with different densities. At a molecular level, viscosity is a result of the interaction between the different molecules in a fluid. This can be also understood as friction between the molecules in the fluid. Just like in the case of friction between moving solids, viscosity will determine the energy required to make a fluid flow.

• Shear stress is the force per unit area required to move one layer of fluid in relation to another.
• Shear rate is the measure of the change in speed at which intermediate layers move with respect to one another.

Viscosity = Shear Stress/Shear Rate

Newtonian vs. Non-Newtonian Fluids:

Isaac Newton, the man to discover this formula, thought that, at a given temperature and shear stress, the viscosity of a fluid would remain constant regardless of changes to the shear rate.

He was only partly right. A few fluids, such as water and honey, do behave this way. We call these fluids Newtonian fluids. Most fluids, however, have viscosities that fluctuate depending on the shear rate. These are called Non-Newtonian fluids.

There are five types of non-Newtonian fluids: thixotropic, rheopectic, pseudoplastic, dilatant, and plastic. Different considerations are required when measuring each of these fluid types. Some of the standard methods of measuring viscosity include:

• Capillary Viscometer: One of the oldest methods of measuring viscosity, the capillary viscometer measures the time between the volume of liquid/sample to pass through the length of the capillary tubes.
• Rotational Viscometer: Measures the torque required to revolve an object within the volume of liquid.
• Falling Sphere Viscometer: Measures the viscosity by dropping a sphere of a specific weight & density and measures the time it takes the sphere to reach designated junctures.
• Zahn Cup Method: Measures by observing the time it takes the volume of liquid to empty the cup though a small hole in the bottom of a container/cups.
• Vibrational Viscometer: By measuring the vibrational waves using a vibrating rod submerged in fluid, viscosity is calculated by analysing the dampening of the vibration.
• VROC Viscometer: This viscometer is pressure driven using a pumping system that the laminar flows to push the liquid into a rectangular slit with pressure sensors, measuring the viscosity of a fluid through the change in pressure after passing each pressure sensor within the microchip.

Valves: Valve is a device that regulates, controls or directs the flow of a fluid by opening, closing, or partially obstructing fluid flow. A valve is a mechanical device that controls the flow and pressure of fluid within a system or Process. So basically, it controls flow & pressure.

Types of Valves

In piping following types of valves are used depending on the requirements. The cost of Valve in the piping system is up to 20 to 30% of the overall piping cost. And the cost of a given type and size of the valve can vary 100%. It means that if you choose ball valve over butterfly valve for the same function. It can cost you more. So, the selection of valves is essential to the economics, as well as operation of the process plants.

▪ Gate Valve
▪ Globe Valve
▪ Check Valve
▪ Plug valve
▪ Ball Valve
▪ Butterfly Valve
▪ Needle Valve
▪ Pinch Valve
▪ Pressure Relief Valve

1. Gate valve Gate valve is the most common type of valve in any process plant. It is a linear motion valve used to start or stop fluid flow. In service, these valves are either in a fully open or fully closed position. Gate valves are used in almost all fluid services such as air, fuel gas, feedwater, steam, lube oil, hydrocarbon, and almost any other services. Gate valve provides a good shutoff.

2. Globe Valve Globe valve is used to stop, start, and regulate the fluid flow. Globe Valves are used in the systems where flow control is required and leak tightness is also necessary. Globe valve provides better shut off as compared to gate valve and it is costlier than gate valve.

3. Check Valve The check valve prevents backflow in the piping system. The pressure of the fluid passing through a pipeline opens the valve, while any reversal of flow will close the valve.

4. Plug Valve Plug valve is a Quarter-turn rotary motion Valve that uses a tapered or cylindrical plug to stop or start the flow. The disk is in plug shape, which has a passage to pass the flow. Plug valve used as on-off stop valves and capable of providing bubble tight shutoff. Plug valve can be used in vacuum to high-pressure & temperature applications

5. Ball Valve A Ball valve is a quarter-turn rotary motion valve that uses a ball-shaped disk to stop or start the flow. Most ball valves are of the quick-acting type, which requires a 90° turn of the valve handle to operate the valve. The ball valve is Smaller and lighter than a gate valve of the same size and rating.

6. Butterfly Valve A Butterfly valve is a quarter-turn rotary motion valve that is used to stop, regulate, and start the flow. Butterfly valve has a short circular body. Butterfly Valve is suitable for large valve applications due to Compact, lightweight design that requires considerably less space, as compared to other valves.

7. Needle Valve Needle valves are similar to a globe valve in design with the biggest difference is the sharp needle like a disk. Needle valves are designed to give very accurate control of flow in small diameter piping systems. They get their name from their sharp-pointed conical disc and matching seat.

8. Pinch Valve The pinch valve is also known as clamp valve. It is a linear motion valve. Used to start, regulate, and stop fluid flow. It uses a rubber tube, also known as a pinch tube and a pinch mechanism to control the fluid. Pinch Valve is ideally suited for the handling of slurries, liquids with large amounts of suspended solids, and systems that convey solid material pneumatically.

9. Pressure Relief Valve A pressure Relief valve or pressure safety valve are used to protect equipment or the piping system during an overpressure event or

in the event of vacuum. This valve releases the pressure or vacuum at predefined set pressure.
In the image below, you can see the difference between opening methods of the
Valve

Applications/ Functions of Valves
Valves serve a variety of functions within the piping system. Such as
▪ Stopping and starting a fluid flow. Depending on whether a valve is open or closed, it lets pass the process fluid or halt the fluid.
▪ Throttling the fluid flow. Some of the valves let you throttle the fluid depending on the open % of total opening. Lesser the opening higher the throttling and otherwise.
▪ Controlling the direction of a fluid flow. Multiport valve lets you decide the way
fluid will go.
▪ Regulating a flow or pressure within the piping system. Some of the automatic control valves maintain the flow and pressure within the system by adjusting opening and closing.
▪ Relieve pressure or vacuum from the piping system and equipment. Pressure and vacuum relief valves safeguard the process system from overpressure and during vacuum conditions.

Classification of Valves Based on Types of Actuator It Used

WHAT IS A FLOW METER ?
A flow metre is a device used to measure the volume or mass of a gas or liquid. Flow metres are referred to by many names, such as flow gauge, flow indicator, liquid metre, flow rate sensor, etc. depending on the particular industry. However, they all measure flow. Open channels, like rivers or streams, may be measured with flow metres. Or more frequently, the most utility from a flow metre and the greatest variety of flow metres focus on measuring glasses and liquids in a pipe. Improving the precision, accuracy, and resolution of fluid measurement are the greatest benefits of the best flow metres.
What is a flow metre and what does it do?
Flow metres are devices that can be used to measure the amount of liquid, or gas which passes through it. It is an instrument which is used to conduct the flow measurement. The flow rate of liquid and gases must be measured accurately for the better quality of the industrial process. Accurate measurement of gases is needed for the industrial process and it also controls the flow rate. Flow metres measure the flow by two methods, some flow metres measure the flow as the amount of the liquid passes through the flow metre

during a period of time. While other flow metres measure the flow by measuring the total amount of fluid that has passed through the flow metre.
Steps to select a flow metre
1 Confirm the properties of the detection fluid
2 Confirm the purpose of measurement and determine the detection method
3 Confirm product specifications
4 Consider cost

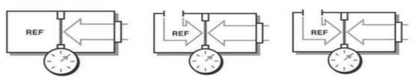
How does a flow metre work?
Flow metre consists of devices such as transducer and transmitter, the transducer will sense the fluid that passes through the primary device. The transmitter will receive a signal from the transducer, so the transducer changes this signal into a usable flow signal. So a flow metre can be considered as the combination of these physical devices.
What are the factors that affect a flow metre selection?
• The phase of the fluid-like gas, liquid, steam
• Flow conditions and flow range, flow conditions like clean, dirty, abrasive, viscous will affect
• Process conditions like pressure and temperature
• Preferred material mostly in case of corrosive fluid
• Pipe size and accuracy
• Repeatability and cost
Different types of Manometres
1. Differential Pressure Flow Metres
Differential pressure flow metres measure the differential pressure across an orifice where flow is directly related to the square root of the differential pressure produced. There are also primary and secondary elements in differential flow metres. The primary element produces change in kinetic energy using either flow nozzle, pilot tube, orifice plate, or venture flow metres. The secondary element measures the differential pressure and provides the signal.
2. Positive Displacement Flow Metres
Positive displacement (PD) flow metres measure the volume filled with fluid, deliver it ahead and fill it again, which calculates the amount of fluid transferred. It measures actual flow of any fluid while all other types of flow metres measure some other parameter and convert the values into flow rate. In PD flow metres, output is directly related to the volume passing through the flow metre. PD flow metres include piston metres, oval-gear metres, notating disk metres, rotary vane type metres, etc.
Positive displacement flow metres are known for their accuracy. They are commonly used in the transfer of oils and fluids, like gasoline, hydraulic fluids as well as in-home use for water and gas applications.
3. Velocity Flow metres

Velocity metres measure velocity of the stream to calculate the volumetric flow rate. These are less sensitive when the Reynolds number of fluid is higher than 10000. Velocity flow metres include turbine, paddlewheel, vortex shedding, electromagnetic and sonic/ultrasonic flow metres.
4. Mass Flow metres
Mass flow metres are more effective in mass related processes as they measure the force that results from the acceleration of mass. More specifically, the force is measured as the mass moving per unit of time, instead of the volume per unit of time. Mass flow metres include Carioles mass metres and thermal dispersion metres. Typical applications for mass flow metres are tied to chemical processes. In addition to the chemical and gas industries, typical industries using mass metres include pharma, power, mining and wastewater.
5. Open Channel Flow metres
Measurement of liquid in open channels include v-notch, weirs and flumes. These dam-like structures, or overflows, allow for a limited or concentrated free-flow of liquids based on the unique shape and size of the structure. This type of flow metre allows for a reading of the flow rate to be calculated. Common applications of open channel metres include free flowing liquids like streams, rivers, and irrigation channels systems.
Manometres
Manometres are precision instruments that are used to measure pressure, which is the force exerted by a gas or liquid per unit surface area owing to the effects of the weight of that gas or liquid from gravity. Depending on the type and how they are configured, manometres can be setup to provide a measurement of different pressure values. A common type of manometer with which most people are familiar is the one that physicians and medical professionals use to measure and monitor a patient's blood pressure. This type of manometer is called a sphygmomanometer.
Following are the three different types of manometres:
1. Simple manometres
2. Differential manometers
3. Micro manometer
Simple Manometer A simple manometer has a glass tube that's one end is connected to a point where pressure is to be measured and the other end remains open to the atmosphere. Common types of simple manometers are:
1. Piezometer
2. U-tube manometer
a) For gauge pressure
b) For vacuum pressure
3. Single Column Manometer

4. Inclined tube manometer or Sensitive Manometer
1. Piezometer For measuring the pressure inside a vessel or pipe in which liquid is there, a tube is attached to the walls of the container or pipe in which the liquid remains so liquid can rise in the tube. By determining the height to which liquid rises and using the relation $p = \rho gh$, a gauge pressure of the liquid can be determined. Such a device is known as Piezometer. To avoid capillary forces, a piezometer tube has to be about 1/2 inch or more. It is essential that the opening of the instrument be tangential to any fluid motion, otherwise an incorrect reading will result.
2. U-tube Manometer
As shown in the figure it consists of a glass tube bent in V-shape, with one end connected to a point at which pressure is to be measured and the other end remains open to the atmosphere.
3. Single Column Manometer
Consider a vertical tube micromanometer connected to a pipe containing light liquid under very high pressure. The pressure in the pipe will force the lighter liquid in the basin to push the heavier liquid downwards. Due to the larger area of the basin, the fall of a heavy liquid level will be very small. This downward movement of heavy liquid into the basin will result in a significant rise of heavy liquid in the right limb.
4. Inclined Tube Manometer
If the vertical tube of the micro manometer is made inclined as shown in figure then it is
called inclined tube micromanometer. This type of inclined micromanometer is more sensitive than the vertical tube type. Due to inclination, the distance moved by the heavy liquid in the right limb is comparatively more. Thus it can give a higher reading for the given pressure.
Differential Manometer
The differential manometer is a device used to measure the pressure difference between two points in a pipe or in two different pipes. A differential manometer consists of a U-tube, containing a heavy liquid, with two ends connected by points whose pressure difference is to be measured:
Types of differential manometers are:
1. Two piezometer manometer
2. U-tube differential manometer
3. Inverted differential manometer
1. Two Piezometer Manometer
It consists of two piezometers mounted at two different gauge points where the pressure difference is to be measured. The pressure difference between two points can be simply measured by the difference in the level of liquid between the two tubes. It possesses some limitations in the form of piezometers.

2. U-tube Differential Manometer
It is a device that is used to measure the pressure difference between two points in a pipe or between two different pipes. This manometer consists of a U shaped tube containing a heavy liquid. The two ends are connected to the two desired points in the pipe whose difference of pressure is required. Let pressure at point A be more than at point B. Then the greater pressure at A will force the heavy liquid in Utube to move downwards. This downwards movement of the heavy liquid in the left limb will cause a corresponding rise of the heavy liquid in the right limb.
3. Inverted Differential Manometer
In this type of manometer, the U-tube is inverted and contains a light liquid. The two ends of the tube are connected to the points whose pressure difference is to be measured. It is used for measuring the difference in low pressures. The figure shows an inverted U-tube a differential manometer connected to the two points A and B. Let the pressure at point A is more than the pressure at point B.
Advantages of Manometres
Following are the main advantages of manometer:
1. It is simple to construct.
2. It has great accuracy.
3. Used to measure pressure, temperature, flow and other process variables.
Disadvantages of Manometres
Following are the main disadvantages of manometer:
1. The manometer has a smaller dynamic response.
2. They are fragile and therefore provide low portability.
3. They have small operational limits which are on the order of 1000 kN/m2.
4. The density of manometric fluid depends on temperature. Therefore, errors may
occur due to change in temperature.

Manometer Applications
• Used in the maintenance of heating, ventilation, and air conditioning (HVAC) systems, low pressure pneumatic or gas systems.
• Construction of bridges, installing swimming pools and other engineering applications.
• Climate forecasting.
• Clinical applications like measuring blood pressure and in physiotherapy.
• Piezometers are used to measure the pressure in pipes where the liquid is in motion.
What is Pressure
Pressure is defined as force per unit area that a fluid exerts on its surroundings. Pressure, P, is a function of force, F, and area, A: P = F/A
The SI unit for pressure is the Pascal (N/m2), but other common units of pressure include pounds per square inch (psi), atmospheres (atm), bars, inches of mercury (in. Hg), millimetres of mercury (mm Hg), and torr.
Pressure measurement methods
A pressure measurement can further be described by the type of measurement being performed. The three methods for measuring pressure are absolute, gauge, and differential. Absolute pressure is referenced to the pressure in a vacuum, whereas gauge and differential pressures are referenced to another pressure such as the ambient atmospheric pressure or pressure in an adjacent vessel.



1 Absolute Pressure 2. Gauge Pressure 3. Differential Pressure
1. Absolute Pressure
The absolute measurement method is relative to 0 Pa, the static pressure in a vacuum. The pressure being measured is acted upon by atmospheric pressure in addition to the pressure of interest. Therefore, absolute pressure measurement includes the effects of atmospheric pressure. This type of measurement is well-suited for atmospheric pressures such as those used in altimetres or vacuum pressures. Often, the abbreviations Paa (Pascal's absolute) or psia (pounds per square inch absolute) are used to describe absolute pressure.
2. Gauge Pressure
Gauge pressure is measured relative to ambient atmospheric pressure. This means that both the reference and the pressure of interest are acted upon by atmospheric pressures. Therefore, gauge pressure measurement excludes the effects of atmospheric pressure. These types of measurements include tire pressure and blood pressure measurements. Similar to absolute pressure, the abbreviations Pag (Pascal's gauge) or psig (pounds per square inch gauge) are used to describe gauge pressure.
3. Differential Pressure
Differential pressure is similar to gauge pressure; however, the reference is another pressure point in the system rather than the ambient atmospheric pressure. You can use this method to maintain relative pressure between two vessels such as a compressor tank and an associated feed line. Also, the abbreviations Pad (Pascal's differential) or PSID (pounds per square inch differential) are used to describe differential pressure.

There are 3 basic methods for pressure measurement;
I. The first method involves balancing the unknown pressure against the pressure produced by a column of liquid of known density.
II. The second method involves allowing the unknown pressure to act on a known are and measuring the resultant force either directly or indirectly.
III. The third method involves allowing the unknown pressure to act on an elastic material and measuring the resultant stress or strain.
Basic equations of Fluid Flow
The basic equations of fluid dynamics, the main task in fluid dynamics is to find the velocity field describing the flow in a given domain. To do this, one uses the basic equations of fluid flow, which we derive in this section. These encode the familiar laws of mechanics:
• Conservation of mass
• Conservation of momentum
• Conservation of energy

Conservation of momentum

The Cauchy equations

Consider a volume V bounded by a material surface S that moves with the flow, always containing the same material elements. Its momentum is fy dV pv, so: rate of change of momentum = $d/dt\int_v$ dV pv = $\int_v$ dV p Dv/Dt

(The mass pdV of each material element is constant.) This must equal the net force on the element. Actually there are two different types of forces that act in any fluid:

• Long ranged external body forces that penetrate matter and act equally on all the material in any element dV. The only one considered here is gravity, pgdV.

Short ranged molecular forces, internal to the fluid. For any element, the net effect of these due to interactions with other elements acts in a thin surface layer. In 3D, each of the 3 sets of surface planes bounding an element experiences a 3-component force, giving 9 components in all. These form the stress tensor [II], defined so the force exerted per unit area across a surface element ds = ñds (by the fluid on the side to which ñ points on the fluid on the other side) is f = [II]..

Total force (body + surface) = ∫ dVpg+ ∫m.ds =∫dV (pg + ▼ - [II]).

By Newton's second law, Eqns. 9 and 10 must be equal for any V, so we get finally the Cauchy equation: p(Dv/Dt) = pg + ▼ - [II]

Conservation of mass

The continuity equation

Consider a volume V bounded by a surface S that is fixed in space. This mass inside it is given by Jy pdV, If mass is conserved, Eqn. 1 must equal the total rate of mass flux out of V. How do we calculate this? The rate of outward mass flux across any small element dS of S is pv ds where the magnitude of dS is equal to the element's area and we take dS along the outward normal.where we used Green's formula to convert to a volume integral.

Concept of boundary layer:
A boundary layer is a thin layer of viscous fluid close to the solid surface of a wall in contact with a moving stream in which (within its thickness δ) the flow velocity varies from zero at the wall (where the flow "sticks" to the wall because of its viscosity) up to Ue at the boundary, which approximately (within 1% error) corresponds to the free stream velocity (see Figure 1). Strictly speaking, the value of δ is an arbitrary value because the friction force, depending on the molecular interaction between fluid and the solid body, decreases with the distance from the wall and becomes equal to zero at infinity.

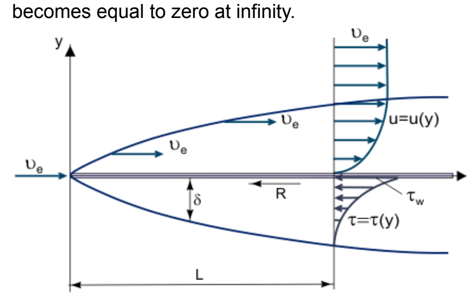


Figure 1. Growth of a boundary layer on a flat plate. The fundamental concept of the boundary layer was suggested by L. Prandtl (1904), it defines the boundary layer as a layer of fluid developing in flows with very high Reynolds Numbers Re, that is with relatively low viscosity as compared with inertia forces. This is observed when bodies are exposed to high velocity air stream or when bodies are very large and the air stream velocity is moderate. In this case, in a relatively thin boundary layer, Friction Shear Stress (viscous shearing force): τ = η[∂u/∂y] (where η is the dynamic viscosity; u = u(y) – "profile" of the boundary layer longitudinal velocity component, see

Figure 1) may be very large; in particular, at the wall where u = 0 and τw = η[∂u/∂y]w although the viscosity itself may be rather small. It is possible to ignore friction forces outside the boundary layer (as compared with inertia forces), and on the basis of Prandtl's concept, to consider two flow regions: the boundary layer where friction effects are large and the almost Inviscid Flow core. On the premises that the boundary layer is a very thin layer (δ << L, where L is the characteristic linear dimension of the body over which the flow occurs or the channel containing the flow, its thickness decreasing with growth of Re, Figure 1), one can estimate the order of magnitude of the boundary layer thickness from the following relationship:

$$\delta / L = Re^{-0.5}$$

Chapter 3 : Material Handling Systems

Pump:
A generic definition of a pump is "A machine or device for raising, compressing, or transferring fluids."
In practice - it is common to differentiate between
• Pumps
• Compressors
• Blowers
• Fans
Pumps
• A pump is a machine for raising a liquid - a relatively incompressible fluid - to a higher level of pressure or head.
Compressors
• A compressor is a machine for raising a gas - a compressible fluid - to a higher level of pressure
Blowers
• A blower is a machine for moving volumes of a gas with moderate increase of pressure
Fans
• A fan moves large amounts of gas with low increase in pressure
Different Types of Pumps: Working and Their Applications
There are different types of pumps available in the market. This article will assist you to know the main functionalities of each type of pump. The type of pump, as well as selection,

mainly depend on our requirements. The application mainly includes the type of fluid you desire to pump, the distance you desire to move the fluid, and the quantity you require to get over a particular time frame. However, it is complicated to recognize accurately what kind of pump you must select. The identifying of the pump can be done with the design as well as positions. To make simpler things while seeking to choose your exact pump, and the pumps can be classified into two types which function in extremely dissimilar ways & generally summarise most of the pump designs.
Types of Pumps
Pumps are classified into two types namely Dynamic pumps as well as Positive Displacement Pumps.

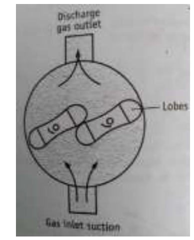
TYPES OF PUMPS
A.) Dynamic Pumps
Dynamic pumps are classified into different types but some of them are discussed below like
1. Centrifugal,
2. Vertical centrifugal,
3. Horizontal centrifugal,
4. Submersible, and
5. Fire hydrant systems.
1) Centrifugal Pumps
These types of pumps are most commonly used worldwide. The working is very simple, described well and carefully tested. This pump is strong, efficient and fairly cheap to make.
Whenever the pump is in action, then the fluid pressure will increase from the inlet of the pump to its outlet. The change of pressure will drive the liquid throughout the system.
This kind of pump produces an enhancement within force by transmitting mechanical power from the electrical motor to the liquid throughout the revolving impeller. The flow of liquid will enter the centre of the impeller and exit along with its blades. The centrifugal power hereby enhances the velocity of fluid & also the energy like kinetic can be altered to force.
2). Vertical Centrifugal Pumps
Vertical centrifugal pumps are also called cantilever pumps. These pumps use an exclusive shaft & maintain design that permits the volume to fall within the pit as the bearings are external to the pit. This mode of pump utilises no filling container to cover the shaft however in its place uses a throttle bushing. A parts washer is the common application of this kind of pump.
3) Horizontal Centrifugal Pumps
These types of pumps include a minimum of two otherwise more impellers. These pumps are utilised in pumping services. Every stage is fundamentally a divide pump.
All the phases are in a similar shelter & mounted on a similar shaft. On a solo horizontal shaft, minimum eight otherwise additional stages can be mounted. Every stage enhances the head by around an equal amount. Multi-stage pumps can also be single otherwise double suction on the first impeller. All kinds of pumps have been providing as well as servicing this type of centrifugal pumps.
4) Submersible Pumps
These pumps are also named as storm water, sewage, and septic pumps. The applications of these pumps mainly include building services, domestic, industrial, commercial, rural, municipal, & rainwater recycle applications.
These pumps are apt for shifting storm water, subsoil water, sewage, black water, grey water, rainwater, trade waste, chemicals, bore water, and foodstuffs. The applications of these pipes mainly include in different impellers like closed, contra-block, vortex, multistage, single channel, cutter, otherwise grinder pumps. For different applications, there is an extensive selection is accessible which includes high flow, low flow, low head, otherwise high head.
5) Fire Hydrant Systems
Fire hydrant pump systems are also named as hydrant boosters, fire pumps, & fire water pumps. These are high force water pumps intended to enhance the capacity of firefighting of construction by increasing the force within the hydrant service as mains is not sufficient.
The applications of this system mainly include irrigation as well as water transfer.
B.) Positive Displacement Pumps
Positive displacement pumps are classified into different types but some of them are discussed below like
1. Diaphragm,
2. Gear,
3. Peristaltic,
4. Lobe, And
5. Piston Pumps.
1) Diaphragm Pumps
Diaphragm pumps also known as AOD pumps (Air operated diaphragms), pneumatic, and AODD pumps. The applications of these pumps mainly include in continuous applications

like in general plants, industrial and mining. AOD pumps are particularly employed where power is not obtainable, otherwise in unstable and combustible regions. These pumps are also utilised for transferring chemical, food manufacturing, underground coal mines, etc.
These pumps are responding pumps and include two diaphragms which are driven with condensed air. The section of air by transfer valve applies air alternately toward the two diaphragms; where every diaphragm contains a set of ball or check valves.
2) Gear Pumps
These pumps are a kind of rotating positive dislocation pump, which means they force a stable amount of liquid for every revolution. These pumps move liquid with machinery coming inside and outside of the mesh for making a non-exciting pumping act. These pumps are capable of pumping on high forces & surpass at pumping high thickness fluids efficiently.
A gear pump doesn't contain any valves to cause losses like friction & also high impeller velocities. So, this pump is compatible for handling thick liquids like fuel as well as grease oils. These pumps are not suitable for driving solids as well as harsh liquids.
3) Peristaltic Pumps
Peristaltic pumps are also named as tube pumps, peristaltic pumps. These are a kind of positive displacement pumps and the applications of these pumps mainly involve in processing of chemical, food, and water treatment industries. It makes a stable flow for measuring & blending and also capable of pumping a variety of liquids like toothpaste and all kinds of chemicals.
4) Lobe Pumps
These pumps offer different characteristics like an excellent high efficiency, rust resistance, hygienic qualities, reliability, etc. These pumps can handle high thickness fluids & solids without hurting them. The working of these pumps can be related to gear pumps, apart from the lobes which do not come into contact by each other. Additionally, these pumps have superior pumping rooms compare with gear pumps that allow them to move slurries. These are made with stainless steel as well as extremely polished.
5) Piston Pumps
Piston pumps are one kind type of positive dislocation pumps wherever the high force seal

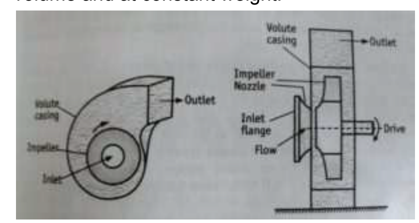
responds through the piston. These pumps are frequently used in water irrigation, scenarios requiring high, reliable pressure and delivery systems for transferring chocolate, pastry, paint, etc.
Thus, this is all about classification of pumps like centrifugal & positive displacement.
These are used in different kinds of buildings to make simpler the movement of liquid materials. The pumps which are used in housing & commercial can handle water. Fire pumps supply a rushed water supply for automatic sprinklers and firefighters, and booster pumps supply clean water to higher floors in apartments. Here is a question for you, what is the function of Hydronic Pumps within HVAC systems?
What is the difference between fan, blower and compressor?
➢ A fan moves large amounts of gas with a low increase in pressure: you'll find these in your home.
➢ A blower is a machine used for moving gas with a moderate increase of pressure: a more powerful fan, if you will. By changing the angle of the blades, a blower will be able to push air in any direction you want it.
➢ A compressor is a machine for raising gas to a higher level of pressure, actually making the air denser by cramming air into a small space.
• In general a fan moves air but not intended to increase air pressure, example are household fans.
• A blower moves air, typically into a restricted space, and has a fair amount higher pressure on the outlet than the intake. Examples are super charger, and leaf blower
• A compressor compresses air (and liquids) to high pressures in a very limited space that is either completely enclosed or having a valve to allow limited release over time such that you have compressed fluid on one side and decompressed fluid on the other side for efficient thermal exchange. Examples are Air Compressors and AC Compressors.
TYPES OF FAN
It is common to classify fans in
• Axial and/or propeller fans
• Centrifugal (radial) fans
• Mixed flow fans
• Cross flow fans
The pressure head of different types of fans with equal periphery speed of the wheel are compared in the capacity diagram below:
Centrifugal fans with forwarded blades are suited for application with higher air flow volumes and pressures. Axial propeller fans are more suited for applications with lower volumes and pressures.
1. Axial and Propeller Fans
In an axial fan the air flows in parallel to the shaft. It is common to classify axial fans upon their wheel like:
• C-wheel - Blades can be adjusted when running. High efficiency, small dimensions, variable air volume
• A-wheel - Blades can be adjusted only when the fan is standing still. High efficiency, small dimensions, adaptive to recommended air volume
• K-wheel - Blades cannot be adjusted. Simple, small dimensions
The pressure head developed for a single stage is up to 300 N/m2. Axial fans are suited for relatively large volumes compared to pressure.
2. Centrifugal fans (Radial fans)
In a centrifugal fan the air flows in a radial direction relative to the shaft. Centrifugal fans can be classified by their wheel like:
• F-wheel - Curved forward blades. High efficiency, small dimensions, and changing in pressure have little influence on the pressure head.
• B-wheel - Curved backward blades. High efficiency, low energy consumption,
Changing pressure has little influence on air volume. Low noise emission, stable in parallel running.
• P-wheel - Straight backward blades. High efficiency, self-cleaning, changing in pressure have little influence on air volume
• T-wheel - Straight radial blades. Self-cleaning. Suitable for material transport
Types of blades used in centrifugal fans are
• Straight steel plate paddle wheel
• Forward multi-vane multi-blade
• Backward turbo-vane
The different blades can be characterised as shown in the capacity diagram below:
3. Mixed flow fans
In a mixed flow fan, the air flows in both axial and radial direction relative to the shaft.
Mixed flow fans develop higher pressures than axial fans.
4. Cross-flow fans
In a cross flow fan, the air flows in an inward direction and then in an outward radial direction.
WHAT IS BLOWER?

Blower is a machine which is used to move air at moderate pressure. OR simply, blowers are used for blowing air/gas in a specific or given area. A blower can develop a maximum pressure of about 202 kilopascals, which is equal to 2 atmospheres.

WORKING PRINCIPLE:
Blowers increase the pressure of the absorbed gas by the centrifugal movement of the impeller. when the impeller is rotating, the channels in the impeller push the air forward by centrifugal movement and a helical movement occurs. Then the gas is continuously compressed along the channel and the pressure increases linearly. Then the pressurised air is transferred from the outlet duct of the blower.
*In a blower the inlet pressure is low and the outlet pressure is high. Because the kinetic energy of the blades increases the pressure of the air at the outlet.
TYPES OF BLOWERS:
Blowers are classified into two types they are
1. Positive displacement blowers
2. Centrifugal blowers
Blowers also use blades in various designs like fans. Such as backward curved, forward curved and radial, they are mainly operated by an electric motor.
1.) Positive Displacement Blowers:
Positive displacement blowers or Rotary air blower is used to move gas or air for a variety of applications.
Positive displacement blowers are almost similar to positive displacement pumps, which squeezes fluid that in turn increases pressure.
Positive displacement blowers are preferred over a centrifugal blower because a high pressure is required in a process.
EX: Cycloidal or Lobe blowers
Cycloidal or Lobe blowers:
Construction:
The general construction of a lobe blower consists of only two or three lobes as rotating parts. They run in close contact with each other and with casing to run efficiently.
Working Principle:
It consists of two or three lobe impellers mounted on parallel shafts, rotating in opposite within a casing closed at the ends by side plates. These blowers are constant volume machines and deliver a fixed discharge of air at a high velocity from the outlet.



Advantages:
1. They provide a large volume of flow which ranges from 30 to 15000m3/ hr.
2. Sustainable energy efficiency
3. Low maintenance time and costs
Disadvantages:
(1) Leakages between the lobes is possible
(2) It produces high noise during working
2.) CENTRIFUGAL BLOWERS:
Centrifugal blowers are also called as turbo blowers
Turbo blowers deliver gases at constant pressure, constant suction pressure, constant volume and at constant weight.



Principle:
In a centrifugal blower the energy is transferred from a rotating shaft to air or gas. A pressure rise is achieved by adding kinetic energy to a continuous flow of air through the rotor or impeller.
Construction:
The construction of the centrifugal blower resembles a centrifugal pump. But in centrifugal blower the parts are made as light as possible and the size is smaller than the centrifugal pump it consists of an enclosed type impeller.
Applications:
1. Wastewater treatment
2. Flue Gas desulfurization and lead recycling
Disadvantages:
1. The cost of the centrifugal blowers is high
2. Since the pressure developed is low, multistage centrifugal blower has to be used for generating high pressure
Compressors, Fans & Blowers – Basic Understanding
Compressors, fans, and blowers are widely used in various industries. These devices are

quite suitable for complex processes and have become indispensable for some specific applications. They have been defined in simple terms as below:

• Compressor: A compressor is a machine which reduces the volume of gas or liquid by creating a high pressure. We can also say that a compressor simply compresses a substance which is usually gas.

• Fans: a Fan is a machine used to move fluid or air. It is operated through a motor via electricity which rotates the blades that are attached to a shaft.

• Blowers: Blower is a machine to move air at a moderate pressure. Or simply, blowers are used for blowing air/gas.

The basic difference between the above three devices is the way they move or transmit air/gas and induce system pressure. Compressors, Fans & Blowers are defined by ASME (American Society of Mechanical Engineers) as the ratio of the discharge pressure over the suction pressure. Fans have the specific ratio up to 1.11, blowers from 1.11 to 1.20 and compressors have more than 1.20.

Types of Compressors

Compressor types can be mainly grouped into two:

1. Positive Displacement Compressor
2. Dynamic Compressor

1. Positive displacement compressors are again of two types:

a.) Rotary
b.) Reciprocating

❖ Types of Rotary compressors are

i) Lobe,
ii) Screw,
iii) Liquid Ring,
iv) Scroll, and
v) Vane.

• Types of Reciprocating compressors are

i) Diaphragm,
ii) Double acting, and
iii) Single acting.

Dynamic Compressors can be categorised into

a.) Centrifugal and
b.) Axial.

Let us understand these in detail.

Positive displacement compressors use a system which induces in a volume of air in a chamber, and then reduce the volume of the chamber to compress the air. As the name suggests, there is a displacement of the component that reduces the volume of the chamber thereby compressing air/gas. On the other hand, in a dynamic compressor, there is a change in velocity of the fluid resulting in kinetic energy which creates pressure.

Reciprocating compressors use pistons where discharge pressure of air is high, the quantity the air handled is low and has a low speed of the compressor. They are suitable for medium and high-pressure ratio and gas volumes. On the other hand, rotary compressors are suitable for low and medium pressures and for large volumes. These compressors do not have any pistons and crankshaft. Instead, these compressors have screws, vanes, scrolls etc. So, they can be further categorised on the basis of the component they are equipped with.

Types of Rotary compressors

• Scroll:

In this equipment, air is compressed using two spirals or scrolls. One scroll is fixed and does not move and the other one moves in circular motion. Air gets trapped inside the spiral way of that element and gets compressed at the middle of the spiral. These are often with oil-free designs and require low maintenance.

• Vane:

This consists of vanes that move in and out inside an impeller and compression occurs because of this sweeping motion. This forces the vapour into small volume sections, changing it into high pressure and high temperature vapour.

• Lobe:

This consists of two lobes which rotate inside a closed casing. These lobes are displaced with 90 degrees to one another. As the rotor rotates, air is drawn into the inlet side of the cylinder casing and is pushed with a force out from the outlet side against the system pressure. The compressed air is then delivered to the delivery line.

• Screw:

This is equipped with two intermeshing screws which traps air between the screw and the compressor casing, which results in squeezing and delivering it at a higher pressure from the delivery valve. The screw compressors are suitable and efficient in low air pressure requirements. In comparison to a reciprocating compressor, the compressed air delivery is continuous in this type of compressor and it is quiet in operation.

• Scroll:

The scroll type compressors have scrolls driven by the prime mover. The scrolls outer edges trap air and then as they rotate, the air travel from outwards to inwards thus getting compressed due to a reduction in the area. The compressed air is delivered through the central space of the scroll to the delivery airline.

• Liquid ring:

In this type of compressor vanes are built inside a cylindrical casing. When the motor rotates, gas gets compressed. Then liquid mostly water is fed into the device and by centrifugal acceleration, it forms a liquid ring through the vanes, which in turn forms a compressing chamber. It is capable of compressing all gases and vapours, even with dust and liquids.

Reciprocating Compressor

• Single-Acting Compressors: It has piston working on air only in one direction. The air is compressed only on the top part of the piston.

• Double-Acting Compressors: It has two sets of suction/intake and delivery valves on both sides of the piston. Both sides of the piston are utilised in compressing the air.

Dynamic Compressors

The main difference between displacement and dynamic compressors is that a displacement compressor works at a constant flow, whereas a dynamic compressor such as Centrifugal and Axial works at a constant pressure and their performance is affected by external conditions such as changes in inlet temperatures etc. In an axial compressor, the gas or fluid flows parallel to the axis of rotations or axially. It is a rotating compressor that can continuously pressurised gases. The blades of an axial compressor are relatively closer to each other. In a centrifugal compressor, fluid enters from the centre of the impeller, and moves outward through the periphery by guide blades thereby reducing the velocity and increasing pressure. It is also known as a turbo compressor. They are efficient and reliable compressors. However, its compression ratio is lesser than axial compressors. Also, centrifugal compressors are more reliable if API (American petroleum Institute) 617 standards are followed.

Types of fans

Depending on their designs, the following are main types of fans:

• Centrifugal fans: In this type of fan, airflow changes direction. They can be inclined, radial, forward curved, backward curved etc. These kinds of fans are suitable for high temperatures and low and medium blade tip speeds at high pressures. These can be effectively used for highly contaminated airstreams.

• Axial Fans: In this type of fan, there is no change in direction of airflow. They can be Van axial, Tube axial, and Propeller. They produce lower pressure than the Centrifugal fans. Propeller-type fans are capable of high-flow rates at low pressures. Tube-axial fans have low/medium pressure and high flow capability. Vane-axial fans have an inlet or outlet guide vanes, exhibit high pressure and medium flow-rate capabilities.

The air flow required in the process along with required outlet pressure are key factors determining the selection of type and size of a fan. Fan enclosure and duct design also determine how efficiently they can work.

Blowers

Blower is equipment or a device which increases the velocity of air or gas when it is passed through equipped impellers. They are mainly used for flow of air/gas required for exhausting, aspirating, cooling, ventilating, conveying etc. Blower is also commonly known as Centrifugal Fans in industry. In a blower, the inlet pressure is low and is higher at the outlet. The kinetic energy of the blades increases the pressure of the air at the outlet.

Blowers are mainly used in industries for moderate pressure requirements where the pressure is more than the fan and less than the compressor.

Types of Blowers:

Blowers can also be classified as Centrifugal and Positive displacement blowers. Like fans, blowers use blades in various designs such as backward curved, forward curved and radial. They are mostly driven by electric motors. They can be single or multistage units and use high speed impellers to create velocity to air or other gases.

Positive displacement blowers are similar to PDP pumps, which squeezes fluid that in turn increases pressure. This kind of blower is preferred over a centrifugal blower where high

pressure is required in a process.
Applications of Compressors, fans and blowers
❖ Compressors, Fans and blowers are mostly used for processes such as Gas
Compression, Water Treatment Aeration, Air Ventilation, Material Handling, Air
Drying etc. Compressed air applications are widely used in various fields such as
Aerospace, Automotive, Chemical Manufacturing, Electronics, Food and Beverage,
General Manufacturing, Glass Manufacturing, Hospitals/Medical, Mining,
Pharmaceuticals, Plastics, Power Generation, Wood Products and many more.
❖ The main benefit of an air compressor includes its usage in the water treatment
industry. The wastewater treatment is a complex process that requires breaking down
millions of bacteria as well as the organic waste.
❖ Industrial fans are also used in a variety of applications such as chemical, medical,
automotive, agricultural, mining, food processing, and construction industries, which

can each utilise industrial fans for their respective processes. They are mainly used in
many cooling and drying applications.
❖ Centrifugal blowers are routinely used for applications such as dust control, combustion
air supplies, on cooling, drying systems, for fluid bed aerators with air conveyor
systems etc. Positive displacement blowers are often used in pneumatic conveying, and
for sewage aeration, filter flushing, and gas boosting, as well as for moving gases of all
kinds in the petrochemical industries.
❖ Compressors, fans, and blowers, largely cover Municipal, Manufacturing, Oil & Gas,
Mining, Agriculture Industry for their various applications, simple or complex in
nature.
❖ These are available from various manufacturers in different designs. Few of the well known
brands are Roots, Hoffman, Bosch, Sutter built, Sullair and Joy.
❖ A detailed study of all the designs and specifications is required to buy an appropriate compressor, fan or a blower that is available in the market so that it can match the
requirements of your process and ensure reliability and durability at the same time.

Chapter 4 : Filtration

Filtration is defined as a process of separation of solids from a liquid by passing it through a porous medium that retains the solids, and allows fluid to pass through.

Slurry :- Solution to be filtered.
Filter media - Porous medium used to retain the solids.
Filter cake - Accumulated solids on filter media.
Filtrate - Clear liquid passed through filter media.

When solids are present in very low concentration (less than 1% w/v) the process is called clarification.

Applications of filtration:-
1. Production of sterile products:-
    a. Air is filtered through HEPA (High Efficiency Particulate air filter) or laminar air bench to obtain sterile air.
    b. A solution is passed through a bacteria proof filter in order to obtain sterile solution.
2. Production of Bulk drugs:-
    a. Solids of intermediates and final product are separate from the reaction mixture by filtration.
    b. Impurity can also be removed.
3. Production of liquid oral formulations:-
    a. Filtration is an essential step in production of oral liquids to get clear solution.
    b. It is used in:-
        i. Dewaxing of oils.
        ii. Removal of suspended oils.
        iii. Removal of undesirable solids.
        iv. Clarification of potable water.

Theories of filtration:-
-The flow of a liquid through a filter follows basic rules of flow of any liquid.
-The rate of flow may be expressed as-
Rate = driving force / resistance
-It is expressed as volume (litres) per unit time.
-The resistance to flow is expressed as-
Resistance to movement = (pressure upstream - pressure downstream)/length of capillaries

Poiseuille's Equation:-
Poiseuille considered the filtration is similar to the streamline flow of a liquid under pressure through capillary.

$$V = \frac{\pi \, \Delta p \, r^4 \, t}{8 \, \eta \, L}$$

V = rate of flow (L/s)
ΔP = pressure difference across the filter (Pascals)
r = radius of the capillary in the filter bed. (m)
L = length of filter cake (m)
η = viscosity of filtrate (Pa.S)

Darcy's Equation :-
The factors influencing the rate of filtration have been incorporated into an equation by Darcy.

$$V = \frac{KA\Delta P}{\eta L}$$

Where, k = permeability coefficient of cake
A = surface area of porous bed.
Kozeny - Carman Equation :-

$$V = \frac{A}{\eta S^2} \times \frac{\Delta P}{KL} \times \frac{\varepsilon^3}{(1-\varepsilon)^2}$$

E = porosity of the cake
S = specific surface area of particles comprising the cake
K = Kozeny constant

Type of filtration
Filtration can be classified :-
1. Depth filtration:-
    a. In this method the removal of suspended material from the liquid suspension is done by passing liquid through a filter bed composed of granular or compressed filter media.
    b. The filter bed is a packed bed of sand, anthracite, or other granular medium.
    c. This method is used in the treatment of surface or potable water supply.
2. Surface filtration:-
    a. Surface filtration involves the removal of solid from a liquid by means of sieving.
    b. The materials that have been used as a filter media include woven wire cloths, cloth fabrics and a variety of synthetic materials.
3. Membrane filtration:-
    a. Membrane filtration is a separation process that uses a semipermeable membrane.
    b. It consists of two steps-
        i. Permeate the liquid passes through membrane and
        ii. Retention of species being separated.

Factors influencing filtration
1. Surface area of filter media:-
    a. According to Darcy's equation the rate of filtration is directly proportional to surface area of filter media.
    b. So the rate of filtration can be increased by increasing the surface area of filter media.
2. Pressure Drop Across the filter media:-
    a. The rate of filtration is directly proportional to the overall pressure drop across filter medium and filter cake.
    b. The pressure drop can be achieved by -
    c. Gravity:-
        i. The pressure developed depends on the density of liquid.
        ii. A head of 10 metres of water creates a pressure difference of 100 kilopascals.
    d. Applying pressure:-
        i. The most common method of obtaining a pressure difference by applying pressure on the surface of slurry.
        ii. It is achieved by pumping slurry onto the filter.
    e. Reducing pressure:-
        i. The pressure below the filter medium may be reduced below atmospheric pressure.
        ii. It is achieved by connecting the filtrate receiver to a vacuum pump.
3. Viscosity of filtrate:-
    a. Rate of filtration is inversely proportional to the viscosity of the fluid.
    b. Raising the temperature of the liquid lowers the viscosity and may increase the rate of filtration.
    c. This is not used when thermolabile materials are involved or filtrate is valable.

Filter media
Filter media act as a mechanical support for the filter cake and is also resposible for the collection of solids.

Characteristics and Ideal Properties:-
1. It should have sufficient mechanical strength.
2. It should be inert.
3. It should not absorb the dissolved material.
4. It should allow the maximum passage of liquid while retaining the solids.

Materials:-
1. Woven materials such as fibre or cloths:-
    a. Woven materials - wool, cotton, silk , glass, metals or synthetic fibres.
    b. Synthetic fibres have greater chemical resistance than wool or cotton.
2. Perforated sheet metal:-
    a. Stainless steel plates have pores are used in metafilter.
3. Bed of granular solid:-
    a. In some processes a bed of granules of solids may be formed to reduce the resistance to the flow.
    b. Examples of granular solids are gravel, sand, asbestos, paper, pulp and kieselguhr.
4. Membrane filter media:-
    a. Cartridge units are economical and available in pore size of 100 μm to even less than 0.2 μm.
    b. They can be used as surface cartridges or depth types.

Filter Aids
The filter aids from a surface deposit which screens out the solids and also prevents the plugging of the filter media.
The object of filter aid is to prevent the blocking of medium and form an open, porous cake.

Characteristics:-
a. Should be chemically inert.
b. Low specific gravity.
c. Insoluble in filtrate.
d. Recoverable.

Examples:-
-Kieselguhr
-Talc
-Charcoal
-Asbestos
-Bentonite
-Fuller's earth

13.1. FACTORS AFFECTING FILTRATION
The following factors affect filtration:
1. The properties of the liquid, such as density, viscosity and corrosiveness.
2. The properties of the solid present, such as particle size, particle shape, particle size distribution and texture of the solid.
3. The proportion of solids in the slurry.
4. Whether the object is to collect the solid, the liquid or both.
5. Whether the solids have to be washed free from the liquid or the solvent.

ROTARY FILTER
Principle: Rotary filter is continuous in operation. It consists of a system that can remove the filter cake. So, they are suitable for filtering the concentrated slurry. They filter the slurry under vacuum through a sieve-like mechanism on a rotating drum surface.
Construction: Rotary drum filter consists of a metal cylinder that is mounted horizontally (Fig. 9.2). The rotary drum is up to 3 metre in diameter and 3.5 metre in length , having an area of 20 metre square. The curved surface is perforated which supports filter cloth of the rotary filter. The drum is radically divided into separated compartments. By an internal pipe each compartment is connected to the centre of the drum through a rotating valve.
working: During operation drum rotates at low speed. The drum just enters the slurry in the trough. When it (drum) dips in the slurry, due to the applied vacuum, the solid is deposited on the drum surface. The liquid filtered through the cloth and enter in an internal pipe and valve and at last it is collected in collecting tank.
After leaving the slurry section, drum enters the drainage area. Special attachment, like cake compression rollers, may be included at this section. By this attachment, the cake is consolidated by the compression mechanism. This process improves the efficiency of the washing and drying process. From the drainage section, the drum enters the water wash area. In this section water is poured on the cake. In order to suck the water wash and air through the solid cake, a separate vacuum system is applied. Wash water is filtered into a separate collecting tank. After leaving the washing zone, the drum enters into the drying zone where hot air is blown on the cake. Finally, the cake is scraped with a knife and then the drum is ready to complete another revolution.

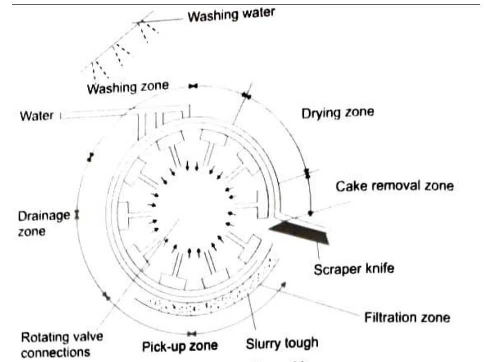


Fig. 9.2: Rotary drum filter

Uses
-It is used for large quantities of slurry.
-It is suitable for slurry containing considerable amounts of solids in the range of 15-30 %.
Advantages
-Filtration area is large
-It is a continuous process and a complete automatic process
-The labour costs are very low
-Thickness of the cake on the drum can be controlled by varying the speed of the drum.
Disadvantages
-The rotary filter is a very expensive process and its functioning is very complex.
-Due to the air drawn through by the vacuum system the cake may break
-The pressure difference should not be more than 1 bar.

META FILTER(EDGE FILTER)
Principle: Meta filters are used as a surface filtration unit for coarse particles. It contains metal rings having semicircular projections which are arranged as a nest to form channels on the edge that offers resistance to the flow of solids.

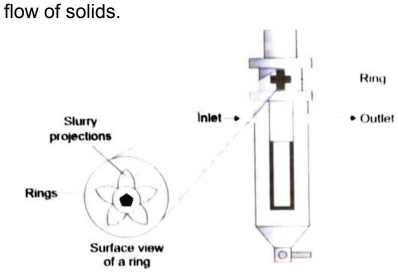


Fig. 9.3A: An edge filter

Construction: Meta filter consists of a series of metal rings (Figs 9.3A and B). The thickness of the ring is about 0.8 mm and inner as well as outer diameters are aout 15 and 22 mm respectively. These rings are threaded to formed channel on the edges. Each metal rings has various semicircular projections on one side of the surface. These projections are arranged the same way up. The rings are tightened on the drainage rod with nut. Hence also known as edge filters. These filters are mounted in a vessels and may be operated by the application of reduced pressure to the outlet direction or by pumping the slurry under pressure. To separate the fine particles from the slurry, first, a bed of a suitable material (e.g. Kieselguhr) is built-up.

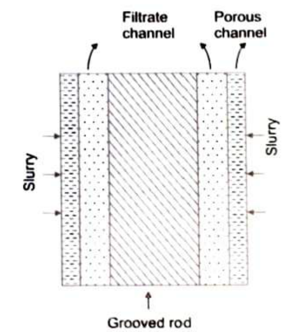


Fig. 9.3B: Mechanism of filtration through metafilters

Working: In it filters are placed in a vessel and operated by pumping the slurry under pressure or occasionally by the applications of reduced pressure to the outlet side. Then the slurry passes through the channels formed on the edge between the rings and clear liquid rises up and gets collected from the outlet into the receiver. It works as a strainer. To separate fine particles a bed of kieselguhr is first built-up. The pack of the rings works as a base on which a true filter medium can be supported.
Uses:
-It is used for syrups clarification.
-It is mainly used for filtering of injections.
-It can be used for viscous liquids
-Meta filter are mostly used for insulin liquours.
Advantages
-Edge filter can be used under high pressure
-Running cost is very low and is very economical process
-They can be easily constructed by such metal that can provide excellent resistance against corrosion.
-Cake can be easily removed by simple back flushing with water
-Sterile product can be easily filtered.
Disadvantages
-The small surface are restrics the collection of solids.

FILTER PRESS

Principle: A filter press is used in separation process, specifically in solid/liquid separation using pressure based principle provided by a slurry pump. It is used in fixed-volume and batch operations, therefore, the operation must be stopped to discharge the filter cake before the next batch can be started. The major components are the skeleton and the filter pack. The skeleton holds the filter pack together while pressure is being developed inside the filtration chamber. The chamber can only hold a specific volume of solids.

Construction: Plate and frame filter is made up of two types of units known as plate and frame. Filter medium usually filter cloth is placed between plate and frames as shown in Fig. 9.4. It may be made by various types of metal to prevent corrosion or metal contamination of the product. Non-metals generally plastic and wood are also used as satisfactory material of construction. There are many types of filter press. The simplest type is open delivery system. It consists of single conduit for introduction of the slurry and the wash and a single opening in each plate for removal of the liquid. Other is closed delivery system. It consists of separate conduits for introducing the slurry and wash water. Some also have separate conduit for removing filtrate and wash water. The conduit may be at the corner, at the centre or at intermediate location. Plate has a studded or grooved surface to support the filter clothe and a outlet for the filtrate.

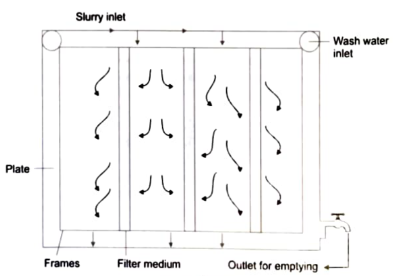


Plate and frame filter press

Chapter 4 : Centrifugation

Definition: Centrifugation is a unit operation used for separating the constituents present in a dispersion with the aid of centrifugal force.
Centrifugal force - is used as driving force -> for separation.
-Centrifugation is useful -> when separation by ordinary filtration is difficult.

-For example -> separation of highly viscous mixture .
-> Colloidal dispersion (particles less than 5 mm)
The equipment used are called centrifuges.

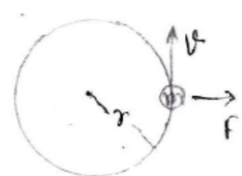
Process of centrifugation:-

-The centrifuge consists of a container in which a mixture of solid and liquid or two liquids is placed -> rotated at high speed -> mixture separated into its constituent parts by action of centrifugal force on their densities.
-A solid or liquid of higher specific gravity is thrown outward with greater force.

Applications:-

1. Production of bulk drugs:-
   a. Centrifugation technique is used to separate -> crystalline drugs form mother liquor (such as aspirin)
2. Production of biological products:-
   a. Proteinaceous drugs macromolecules - present in water as colloidal dispersion -> centrifugal force is used to separate them from water.
   b. Insulin can be obtained in pure form -> by selective precipitation of other fraction of proteins -> subsequently separated by ultracentrifugation.
   c. It is used to separate blood cells from blood.
3. Biopharmaceutical Analysis of drugs:-
   a. Drugs present in -> (blood, tissue fluid, urine) -> Are present in the form of colloidal dispersion -> centrifugation is used for separating the drugs.

Types of centrifugation:
Consider a body of mass m kg rotating in circular path of radius r metres at a velocity v metre per minute



The force acting on the body in a radial direction is given by

- **Force acting in radial direction f = mv/r -(1)**
- **Where f is centrifugal force**
- **Gravitation force G = mg -(2)**
- **Where g = acceleration due to gravity.**

The centrifugal effect is expressed as a ratio of centrifugal force to gravitational force.
Centrifugal effect $C = F/G = mv^2/rmg = v^2/\mu g$ -(3)
But $v = 2\pi rn$ where n = speed of rotation (revolution per sec)
$C = (2\pi rn)^2/gr - 4\pi^2r^2n^2/gr$
$C = 4\pi^2rn^2/g$
2r = d where d is diameter of rotation
$C = 2\pi^2dn^2/g$
As $g = 9.807\ m/s^2$, $\pi = 3.14$
So $C = 2 \times (3.14)^2 \times dn^2/9.807$
$C = 2.014\ n^2d$

Chapter 5 : Crystallization

In some solutions, under certain conditions, the solutes, separate-out, in the form of crystals. This process is called ‘Crystallisation’. This is one of the unit operation, mainly used in solvent to the impure substance to form a solution. It is filtered to remove the insoluble impurity matters, if present. Then the process of Crystallisation is effected by any one of the following unit operations:

1. Making the solution to supersaturation by cooling directly or indirectly.
2. Making the solution to supersaturation by evaporating the solvent partially.
3. Converting or changing the solution to supersaturation by adiabatic evaporation, that is cooling with evaporation.
4. Salting out the substance (solute) by adding another electrolyte substance that reduces the solubility of the solute in question. This is known as common ion effect.

Impure substance + solvent -Filter> Filtered solution -> (1. Cooling, 2. Evaporation, 3. Salting out.)

[Note: Substances obtained by the process by the sublimation, i.e., solid to vapour and sublimes as crystalline form, bypassing the state of liquid form, has not been studied under this unit operation Crystallisation. Only crystals obtained from liquid state state are dealt here.]

Definition:A crystal may be defined as "a homogenous particle of solid which is formed by solidification under favourable conditions, of a chemical element or a compound, whose boundary surfaces are planes symmetrically arranged at definite angles to one another in a definite geometric form".

Market Demand

The requirements of industry in crystallisation are

1. Highest yield.
2. Purest, i.e., high purity with minimum impurities.
3. Crystal size and shape.
4. Low cost.

Role of Heat

Heat transfer plays a major part in the crystallisation process. The heat includes sensible heat, latent heat and the heat of Crystallisation. With substances whose solubility increases with increase in temperature, there is an absorption of heat, when the substance dissolves.
In substances with decreasing solubility, as the temperature increases, there is an evolution of heat when solution occurs. when there is no change in solubility with change in temperature, there is no heat effect.
Examples of substances whose solubility decreases in water with increase in temperature are - Calcium acetate, Calcium hydroxide, chlorine, bromine, hydrobromic acid, carbon dioxide, sulphur dioxide, nitric oxide and nitrous oxide.
At equilibrium, the heat of Crystallisation is equal and opposite in sign to the heat of solution. (Heat of solution can be exothermic or endothermic). Using the heat of solution at infinite dilution as equal, but opposite in sign to the heat of Crystallisation is equivalent to neglecting the heat of dilution. With many materials the heat of dilution is small in comparison with the heat of solution and hence the approximation is justified; However there are some exceptions. Relatively large heat effects are usually found in the crystallisation of hydrated salts. In such cases, the total heat released by this effect may be a substantial portion of the total heat effects in a cooling type crystallizer. In evaporative type crystallizers, the heat of crystallisation is usually negligible when compared with the heat of vaporisation of the solvent.

Miers Theory of Supersaturation

Mier's theory states that "in a solution completely free from any foreign particles, spontaneous Nucleation occurs at supersaturation and not near the saturation concentration". But this has several limitations and hence of no significant use in actual practice.
Crystal growth is a layer by layer process. First a nucleus forms which then grows to bigger size.
The mechanism of crystallization of substances from the solution involves three steps:

a. Supersaturation - cooling/evaporation.
b. Nucleus formation - Nucleation may occur spontaneously or it may be induced

artificially. Nucleation is classified as primary nucleation and secondary nucleation.
Primary nucleation is the nucleation in the systems that do not contain any crystalline matter. Secondary nucleation represents the condition where nuclei are
generated in the vicinity of crystals present in a supersaturated solution.

Nucleation
1. Primary
    a. Homogenous (spontaneous)
    b. Heterogenous
2. Secondary
    a. Initial breeding
    b. Collision breeding
    c. Needle breeding

C. Crystal growth is a diffusion process and surface phenomenon. This takes place at super saturated concentration level.
Solution -> Supersaturated solution -> Loose Aggregates -> Nuclei Nucleation -> -Diffusion and Deposition> Crystal growth

In the science of Crystallography, the crystals are classified according to the angles between faces - as Cubic, Tetragonal, Orthorhombic, Hexagonal, Monoclinic and Triclinic.

Conditions of Mier's Theory
In a solution ions or molecules can interact to form short lived cluster which develops into embryos or sub-nuclei, many of which failed to achieve maturity. They redissolve due to their extreme instability. When these aggregates attain the size at which cohesive critical nucleus is formed. Thus Mier's theory points out that the greater the degree of supersaturation, the more chance there is of nuclei forming. Also if the supersaturation passes a certain range of values, nucleus formation is apt to be extremely rapid.

Limitations of Mier's Theory
I. The solution must be free from foreign particles, but in practice it is difficult to avoid contamination, especially from the atmosphere.
II. Mier's Theory postulated with experiments of smaller volume of solution, whereas with large volume of batches in industrial practice nucleation takes place spontaneously at lower degree of saturation. This may be attributed to the contamination taking place in handling large volumes, which increases the chances of collision.
III. Likewise, when the solution of lower degree of supersaturation kept for longer period, due to more chances of contamination leading to collisions effecting spontaneous nucleation.
IV. Due to above, the nucleation takes place not at a particular supersaturation concentration, but at a zone of supersaturation in the system. Thus a specific concentration cannot be fixed for individual systems.
V. Apart which from the above factors, the system is subjected to external stimulus like mechanical shock, vibration etc., which changes the ideal conditions of Mier's theory of nucleation.

CRYSTAL HABIT
Crystal is a polyhedral solid with a number of planar surfaces. The arrangement of these faces is termed as habit. In other words, the term crystal habit is used to denote the relative development of the different types of faces. For example, sodium chloride crystallizes from aqueous solutions with cubic faces only. On the other hand, if sodium chloride is crystallized from an aqueous solution containing a small quantity of urea, the crystals obtained will have octahedral faces. Both types of crystals belong to the cubic system but differ in habit. The question of whether a material crystallizes in symmetrical crystal, in plates or needles or prisms is usually an accident resulting from the condition under which it is grown and has no relation either to its crystallographic classification or its habit. The word habit is sometimes wrongly used to designate these features of external form, but when properly used, it refers to the type of faces developed and not to the shape of the resulting crystals. (This much knowledge is enough for a pharmacist, as Crystallography in itself is a separate study and dealt with in detail by chemical engineers.)

FACTORS OF CRYSTAL GROWTH
The factors that effect the rate of crystal growth are :
1) Rate of diffusion of the solute from the mass of solution to the interface.
2) Magma density - which is the ratio of solid to mother liquor in the circulating material. Heavier magma will produce larger crystal surface.
3) Rate of circulation.
4) Amount of vacuum in the system
5) Operating temperature

CLASSIFICATION OF CRYSTALLIZERS
Equipments used to obtain crystals by the unit operation crystallization are called crystallizers. They are classified based on the type of other unit operation involved in the process, which are stated in the beginning above.
I. Supersaturation by cooling alone.
    A. Batch processes
        1. Static tank crystallizers
        2. Agitated batch crystallizers
    B. Continuous processes
        1. Swenson-Walker crystallizer.
        2. Others.
II. Supersaturations by evaporation of the solvent
    A. Saltin evaporators - Swenson crystallizer
    B. 1. Krystal crystallizer
       2. Swenson circulating Magma crystallizer.
III. Supersaturation by adiabatic evaporation (i.e., cooling plus evaporation) Vacuum Crystallizers.
    A. With external classifying seed bed.
    B. Without external classifying seed bed.
IV. Supersaturation by salting out.

Static Tank Crystallizer
Hot and nearly saturated solution is made, filtered and transferred to open rectangular tanks made up of materials which are resistant to the corrosive effect of the solution. Cooling of solution is effected by natural convection and radiation. Glass enamelled or S.S. vessel of 0.5m is generally used. No agitation inside the tank. Insulation may be used to the tank in order reduce the rate of cooling in the initial phase of the cycle and prevent the formation of too many nuclei. Surface cooling may be increased by a jacket outside the tank in which chilled water circulated in the later phase. The empty jacket will act as insulation in the first phase.
Crystals grow slowly and form in large size and considerable interlocked. This interlocking results in the occlusion of mother liquor, thus introducing impurities in it. When the tanks had cooled sufficiently which is normally a matter of several days, any mother liquor remaining is drained off and crystals removed by hand or with blunt shovel. A battery of such vessels is used in practice. Large floor space is required and the process takes long time. More labour required but still preferred because of its inexpensiveness in some places. No running cost on electricity. Though better crystallizers are available, this is still used in the production of Glaber's salt

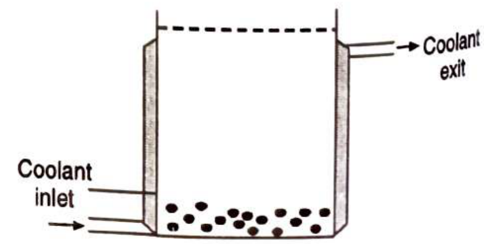


Fig. 18.1. Tank crystallizer.

(Na_2SO_4) and for small scale operations. This method is adopted in under-developed areas,
where the labour cost is extremely low and no skill required. Rods or strings can be hung
in the tanks to give the crystals additional surface on which to grow.

Agitated Tank Crystallizer
Saturated solution is made to supersaturation by cooling. To hasten-up the
Crystallization process, artificial cooling coils as well as jacketed coverings are adopted.
Agitation by slow moving propellers with paddles attached is used (no cutting sharp
edged blades). (Fig. 18.2) This slow agitation performs two functions-first, it increases
the rate of heat transfer and keeps the temperature of the solution more uniform; second,
by keeping the fine crystals in suspension, it provides them more opportunity to grow
uniformly instead of forming large crystals or aggregates. The product obtained by this is
not only more uniform but also very much finer than that from the older static tanks.

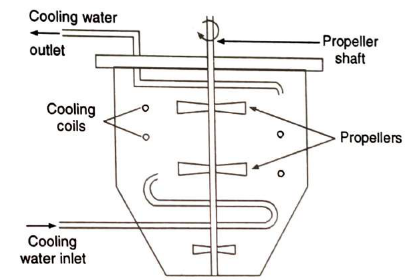


Fig. 18.2. Agitated batch crystallizer.

Drawbacks of agitated Tank Crystallizer
a. It is a batch operation and not continuous.
b. The solubility is least at the surface of the cooling coils. Consequently the growth is more rapid at these points and the coils build-up

with a mass of crystals very fast, that decreases the rate of heat transfer.

It is recommended that the temperature difference between the tube wall and the solution shall not exceed 10ºC so as to prevent crystal deposition. This is the best choice for fine chemicals and some pharmaceuticals, where fine crystals are preferred and the rate of production is comparatively low.

Swenson Walker Crystallizer

Swenson walker crystallizer is a continuous operation crystallizer based on supersaturation by cooling. It consists of an open trough two feet wide and ten feet long with a semi-cylindrical bottom, a water jacket welded to the outside of the trough and a slow speed, long pitch spiral agitator running at about seven rpm and set very close to the

Circulating Magma Crystallizer

(Magma is the term used for solutions suspended with crystals).

This is a modification of vacuum crystallizer in which growing crystals are brough intentionally to the zone of the crystallizer where supersaturation is being created. The zone of generation of supersaturation is the boiling surface. The presence of growing crystals in the zone where supersaturation is created immediately utilizes this driving force, and the real supersaturation level is therefore considerably lower than other types .

FACTORS THAT AFFECT THE RATE OF CRYSTAL GROWTH

1. Rate of diffusion of the solute from the mass of the solution to the interface.
2. Magma density, which is the ratio of solid to mother liquor in the circulating material. Heavier magma will produce larger crystal surface.
3. Rate of circulation
4. Amount of vacuum
5. Cooperating temperatures.

In all forced circulation crystallizers, the size of the crystalline material produced varies with the operating parameters and the characteristics of the material being handled. With sodium chloride, urea, citric acid and many similar inorganic and organic chemicals, the Crystalline products are in the range of 20 to 150 mesh sizes.

CAKING OF CRYSTALS

Caking of crystalline substances is the tendency of the crystals to cake or bind together

This is troublesome in bulk storage and in large containers, as it will be difficult to remove the material or to transfer into other containers. It may not be so serious in small packings. The extent of caking may vary from formation of loose aggregates that fall apart between the fingers to that of solid lumps that have to be crushed with considerable force. Consumers will not like this and hence demand a free flowing material. Thus prevention of caking is a serious problem to the bulk manufacturer.

If a crystal of soluble salt is in contact with air that contains less water than would be in equilibrium with the saturated solution of the salt, the crystal will remain dry since if the crystal were to be surrounded with a film of its solution, that solution necessarily evaporates. On the other hand, if the crystal is brought into contact with air containing more moisture that would be in equilibrium with its saturated solution, then the crystal will become damp and in time will absorb water until it is first completely dissolved and finally until the solution becomes so dilute that it is in equilibrium with the air.

Following steps are adopted to prevent the caking crystals:

1. Maximum critical humidity of the substance obtained by removing impurities to the maximum extent. The critical humidity of a solid salt is the humidity above which it will always remain dry. If the salt is coated with impurities derived from the mother liquor during Crystallization and subsequent separation, this may result in a critical humidity higher or lower than that of the pure salt depending on whether the impurities give the solutions greater or lesser vapour pressure than that of the salt in question.
2. Producing a more uniform mixture of crystal size thus increasing the percent of voids. For a given crystal form and for absolutely uniform sized crystals, the percent of voids is the same irrespective of the crystal size. Non-uniformity of particle size rapidly decreases the percent voids. On the other hand a fine product has more points of contact per unit volume than a coarse one and hence a great tendency to cake.
3. Coating with a powdery material that can absorb moisture and protect the crystal. This method will not be possible with active medicaments, even if material the coating is inert, as the potency will come down considerably. Examples in other fields are:

(a) dusting of table salt with magnesia or Tricalcium phosphate, and

(6) the coating of flake calcium chloride with 25% H,O with anhydrous calcium chloride.

APPLICATION OF CRYSTALS/CRYSTALLIZATION IN PHARMACY

1. Purification of drug-recrystallization technique.
2. Change in micromeritics-free flowing, compressibility, wettability, prolonged and improved bioavailability.
3. Ease of handling in transport and storage.
4. Better chemical stability.
5. Physical stability-improvement in suspension and in tablet hardness.

Chapter 6 : Dehumidification and Humidity Control

Dehumidification is a unit operation in which the moisture present in the air is removed and made dry to the required level (concentration). It can also be called as drying in the air.

The reverse process i.e. increasing the moisture content in the air and making it more wet, ais also a unit operation and known as Humidification. Application of this in Pharmaceutical industry is very much limited and negligible. Air with increased moisture content is essential in the growth of certain organic cultures. Humidification is extensively used in textile industry, where sections like spinning and weaving require a relative humidity of 70 % to 90%. Hence humidification process and related matters are not dealt here. Dehumidification is very much employed in Pharma industry for several purposes. Hence a detailed study of this unit operation becomes essential. Dehumidification of air can be achieved by condensing the water vapour present in air as moisture to the liquid from water and removing it. The same object of removing water vapes can also be achieved by absorbing and absorbing the water vapours on suitable media and thus making the air dry. These transfer processes depends upon the temperature and mixture content that are already present in the air. It is an equilibrium process. In the normal environmental conditions, the air has a certain humidity which differs in day time and night time, from season to season in the country, as also from place-to-place like coastal and non-coastal areas geographically. But in industry, air with a steady and constant humidity is required throughout the process and in whole year to achieve quality of product and to get good yield.

PSYCHROMETRIC CHART

Psychrometric chart is also called as Humidity chart or Hygrometric chart. In this chart humidities (expressed as pounds of water per pound of dry air) are plotted as ordinates against (Fahrenheit or centigrade) temperatures as abscissas for a pressure of 1 atmosphere. Any point on this chart represents the temperature and humidity of a definite sample of air. The curved line marked "100%" gives the humidities of saturated air at various temperatures. Mixtures of air and water vapour represented by points above and to the left of the saturation line cannot ordinarily exist. The curved lines below the line for saturated air represent various per cent humidities. The line for humid heat is plotted with humidities from right-hand edge of the chart as ordinates, against BTU along the top of the chart as abscissas. The lines for the specific volume of dry air, and for the saturated volume, are plotted with temperatures as abscissas and cubic feet per pound of dry air along the left edge of the chart as ordinates. The humid volume of a sample of air at a given temperature and humidity can be found by linear interpolation between the line for saturated volume and the line for the specific volume of dry air.

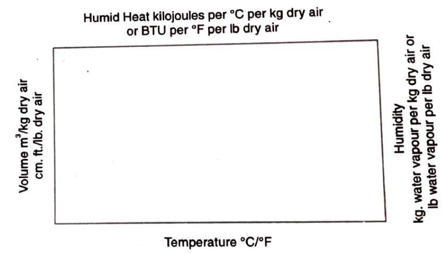


Fig. 11.1. Psychrometric chart model.

MEASUREMENT OF HUMIDITY AND RELATIVE HUMIDITY

I. Dew Point Method

The dew point of wet air is measured directly by observing the temperature at which moisture begins to form on an artificially cooled polished surface. The polished surface is usually cooled by evaporation of a low boiling solvent such as ether; by vaporisation of a condensed gas such as CO_2 or liquid air, or by a temperature regulated stream of water. Referring to the humidity chart, the humidity of the area corresponding to the dew point can be found. Although the dew point method may be considered a fundamental technique for determining humidity, several uncertainties occur in its use. It is not always possible to measure precisely the temperature of the polished surface or to eliminate gradients across the surface. It is also difficult to detect the appearance or disappearance of fog; the usual practice is to take the dew point as the average of the temperature when fog first appears on cooling and disappears on warming.

II. Wet-Bulb Method

The most commonly used method for determining the humidity of a gas stream is the measurement of wet and dry bulb temperature. The wet bulb temperature is measured by contacting the air with a thermometer whose bulb is covered by a wick saturated with water. If the process is adiabatic, the thermometer bulb attains the wet bulb temperature. When the wet and dry bulb temperatures are known, the humidity is readily obtained from the psychometric chart. In order to obtain reliable information, care must be exercised to ensure that the wet bulb thermometer remains wet and that radiation to the bulb is minimal. Again, as with the dew-point method errors associated with the measurement of temperature can cause variation and difficulty.
Use of Humidity Chart. (i) From the dew point temperature go up on the y-axis to point
(a) on the 100% saturation line. Following from this point horizontally on x-axis will
give the humidity H (See Fig. 11.2).

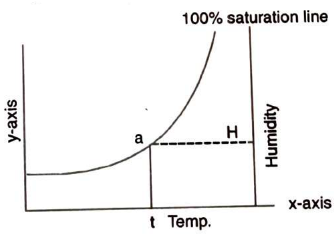


Fig. 11.2. Humidity chart (a portion).

Uses of Dehumidifiers in Pharmacy

1. In the manufacture of empty hard gelatin capsules.
2. In the hard gelatin capsules powder mixing, filling, sealing and packing areas.
3. In the manufacture of soft gelatin capsules.
4. In the manufacture of dry syrup preparations.
5. In the processing, filling and packing of hygroscopic powder dosage form and nutrition products.
6. In the tablet manufacturing, punching and packing areas, as the moist atmosphere may pose sticking and pitting problems.
7. In sugar coating and film coating of tablets.
8. In the antibiotic powder processing areas and dry powder filling in vials, as most of the antibiotic powders are quite hygroscopic. If they absorb moisture during processing and filling, their potency may come down fast and they may form lumps and cakes which will not go into the solution when reconstituted by the physician before injecting them to patients.

DEHUMIDIFICATION EQUIPMENTS

The moisture present in the air is physically absorbed using suitable material known as desiccant. This may be carried out as a batch operation or on a continuous basis. Desiccant is a material which attracts water vapour, causing it to condense upon its surface, without absorbing or being absorbed, by the moisture. Its physical structure does not change in the process. e.g. Silica gel, Alumina, Calcium chloride, Anhydrous sodium sulphate, HSO, acid, Glycerol, P,O, LiCl (silica gel and Alumina Al,O, are adsorbing type rest are absorbing types).
(A) In the batch process, there is no movement of the desiccant-they are periodically
removed, recharged and loaded back into the system. At the best, they may be loaded on
circular discs or plates, connected centrally through a shaft and to a motor running at a
very slow speed for easy unloading and loading of desiccants. Fig. 11.11.
(B) The continuous physical adsorption process unit consists of two parts- Dehumidification sector and Reactivation sector. There is a perforated metal bed rotating clockwise moving through both the sectors in a cycle. The two sectors known as compartments are isolated by silastic seals. Desiccants are charged on the perforated disc bed. Small blowers are provided for the fresh air and hot air flow.

Chapter 7 : Refrigeration System

Refrigeration is the process of cooling a space, substance, or system to lower or maintain
its temperature. In other words, refrigeration means artificial (human-made) cooling
system. Energy in the form of heat is removed from a low-temperature reservoir and
transferred to a high-temperature reservoir. Refrigeration has many applications,
including household refrigerators, industrial freezers, cryogenics, and air
conditioning. Heat pumps may use the heat output of the refrigeration process, and also
may be designed to be reversible, but are otherwise similar to air conditioning units.
Refrigeration has had a large impact on industry, lifestyle, agriculture, and settlement
patterns. The idea of preserving food dates back to at least the ancient Roman and
Chinese empires. However, mechanical refrigeration technology has rapidly evolved in the
last century, from ice harvesting to temperature-controlled rail cars. The introduction of refrigerated rail cars contributed to the westward expansion of the United States, allowing
settlement in areas that were not on main transport channels such as rivers, harbours, or
valley trails. Settlements were also developing in infertile parts of the country, filled with
newly discovered natural resources.

How Does A Refrigerator Work?

To put it simply there are 3 steps by which a refrigerator or a fridge works:
1. Cool refrigerant is passed around food items kept inside the fridge.
2. Refrigerant absorbs heat from the food items.
3. Refrigerant transfers the absorbed heat to the relatively cooler surroundings
outside.

Although there were techniques that people used in ancient times to get cold water, they
were certainly not as easy as opening a door at home and taking out a bottle of ice cold
water. Even if they could get cold water to drink, they certainly didn't have anything
that could make their food stay fresh for days or even weeks on end.
Fortunately, we have a little something that does all of these things for us – a refrigerator!
We will take a look at the science of a refrigerator, specifically the different parts of a
refrigerator and how they actually work together to preserve our food for extended periods.

Refrigerator working principle

The working principle of a refrigerator (and refrigeration, in general) is very simple: it
involves the removal of heat from one region and its deposition to another. When you
pass a low-temperature liquid close to objects that you want to cool, heat from those
objects is transferred to the liquid, which evaporates and takes away the heat in the
process.
You may already know that gases heat up when you compress them and cool down when
they are allowed to expand. That's why a bicycle pump feels warm when you use it to
pump air inside a tire, while sprayed perfume feels cold.
he tendency of gases to become hot when compressed and cold when expanded, along
with the help of a few nifty devices, helps a refrigerator cool the stuff being kept inside it.

Parts of a refrigerator

A refrigerator consists of a few key components that play a vital role in the refrigeration
process:

Expansion valve

Also referred to as the flow control device, an expansion valve controls the flow of the
liquid refrigerant (also known as 'coolant') into the evaporator. It's actually a very small
device that is sensitive to temperature changes of the refrigerant.

Compressor

The compressor consists of a motor that 'sucks in' the refrigerant from the evaporator and
compresses it in a cylinder to make a hot, high-pressure gas.

Evaporator

This is the part that actually cools the stuff kept inside a refrigerator. It consists of finned
tubes (made of metals with high thermal conductivity to maximise heat transfer) that
absorb heat blown through a coil by a fan. The evaporator absorbs heat from the stuff
kept inside, and as a result of this heat, the liquid refrigerant turns into vapour.

Condenser

The condenser consists of a coiled set of tubes with external fins and is located at the rear
of the refrigerator. It helps in the liquefaction of the gaseous refrigerant by absorbing its
heat and subsequently expelling it to the surroundings.
As the heat of the refrigerant is removed, its temperature drops to condensation
temperature, and it changes its state from vapour to liquid.

Refrigerant

Also, commonly referred to as the coolant, it's the liquid that keeps the refrigeration cycle
going. It's actually a specially designed chemical that is capable of alternating between
being a hot gas and a cool liquid.
In the 20th century, fluorocarbons, especially CFCs, were a common choice as a
refrigerant. However, they're being replaced by more environment-friendly refrigerants,
such as ammonia, R-290, R-600A etc.

Refrigerator function: How does a refrigerator work?

The refrigerant, which is now in a liquid state, passes through the expansion valve and
turns into a cool gas due to the sudden drop in pressure.
As the cool refrigerant gas flows through the chiller cabinet, it absorbs the heat from the
food items inside the fridge. The refrigerant, which is now a gas, flows into the
compressor, which sucks it inside and compresses the molecules together to make it into
a hot, high-pressure gas.

Now, this gas transports to the condenser coils (thin radiator pipes) located at the back of the fridge, where the coils help dissipate its heat so that it becomes cool enough to condense and convert back into its liquid phase. Because the heat collected from the food items is given off to the surroundings via the condenser, it feels hot to the touch.
After the condenser, the liquid refrigerant travels back to the expansion valve, where it experiences a pressure drop and once again becomes a cool gas. It then absorbs heat from the contents of the fridge and the whole cycle repeats itself.

APPLICATIONS OF REFRIGERATION IN 7 DIFFERENT INDUSTRIES

Refrigeration and cooling systems are designed to fulfil determined requirements based on the specific characteristics of each industry. The main industries that require refrigeration or cooling systems are:
1. District Cooling
2. Electricity Production
3. Chemical and Petrochemicals
4. Pharmaceutical
5. Food & Beverages
6. Data Centers
7. Other industries

1. DISTRICT COOLING

One of the top markets for cooling is focused on providing cooled air to urban and touristic areas, thus keeping enclosed ambiances comfortable independently of the outside weather. In big hotels, resorts and district areas, refrigeration production is usually delivered by District Cooling systems.
The concept of District Cooling is based around the generation of cooling streams (mainly chilled water) with different technologies in a central plant. It is then distributed to different populated places like homes, offices, venues, or other residential or commercial projects. By centralising the cooling production, a higher efficiency is achieved. This, due to optimization of industrial equipment and electricity consumption compared to individual refrigeration systems for each building. In addition, District Cooling has other advantages, like a reduction in capital, operation, and maintenance costs with respect to individual cooling systems. Combined with energy storage systems, a considerable reduction in peak electricity demand can be achieved. District Cooling provides important

economic and environmental benefits to residential communities and touristic areas.

2. ELECTRICITY PRODUCTION

Electricity generation is often based on the combustion of different fuels. To achieve a higher efficiency, inlet air must be in determined conditions. If the temperature of the inlet air is too high, its density decreases, suffering a decline in the electric production. To avoid this problem, systems like Turbine Inlet Air Cooling System, a system in ARANER's portfolio, are used to cool down these air streams.
Other parts of production and distribution systems, like electric generators or distribution plants, also generate heat when operating. To minimise maintenance operations, refrigeration systems are necessary. This refrigeration equipment is usually based on compression or absorption Cycles.

3. CHEMICAL & PETROCHEMICAL

Although chemical and petrochemical reactions are not as strictly controlled as the reactions in the Pharmaceutical field, control of temperature is an important factor in reaching high efficiency in their transformations. Distillations, crystallizations or condensations are operations requiring the removal of heat; hence refrigeration systems are necessary to obtain their products. In chemical and petrochemical industries, large scale cooling plants are used in their processes. Due to the high flow required and the location of the industries, river water or seawater is used as refrigerant. Compression cycles and absorption cycles are used to cool down the hot stream after the heat has been dissipated in the different operations. Moreover, since hot streams are also required in other parts of the process, heat exchangers are usually applied to heat these streams and maximise the efficiency of the operation.

4. PHARMACEUTICAL

The Pharmaceutical industry is based around operations where fulfilment of strict conditions is essential for the success of every process. Going further, many production procedures imply biological or biochemical reactions that only take place in strict conditions in which microbiological species generate chemical compounds at their maximum yield. This is why it is so important that Pharmaceutical firms develop their products in clean disinfected rooms.

One of the most important parameters in this industry is temperature. Moreover, strains used for drug and medicine production are stored in very controlled conditions, usually at low temperatures. For these reasons, the Pharmaceutical industry must rely on highly sophisticated refrigeration systems that permit the temperature adjustment of rooms and storage units to extremely precise temperatures.
For Pharmaceuticals, the size of cooling plants tends to be smaller, since the production capacity of pharmaceutical industry equipment is limited. Normally, this industry utilises a central cooling plant with transformer stations and refrigerants that are distributed through the different clean rooms of the factory. Other refrigeration systems that can be found in this industry are oxy-chlorination plants, ammonia/chlorine/oxygen liquefaction plants, or compressed air cooling.

5. FOOD & BEVERAGES

Maintaining the cold chain in the F&B industry is vital for preserving products and avoiding possible microbiological contamination. Each product has its own optimal conditions for storage and preservation. In the preparation process, temperature is one of the most important parameters to assure food safety. In products like fish, poultry, meat, dairies or fruits, refrigeration systems are necessary to keep products in low temperatures and extend the recommended consumption period. Other types of F&B industries—like a brewery—require several refrigeration systems to finish the biological and chemical reactions that take place during the process, and to preserve the optimal conditions of the product once the process is finished.

6. DATA CENTRES

Data centres store groups of servers used to process and distribute data. The servers naturally produce heat during operation, and if the heat is not removed, the temperature rises. Unfortunately, this can adversely affect the functioning of the servers. To prevent this problem, powerful air-cooling systems are usually placed in these data centres, dissipating the heat produced and minimising maintenance operations. These cooling systems are commonly air-based or liquid-based, depending on exterior conditions.
Furthermore, new cooling systems are starting to be more environmentally friendly, using seawater as a refrigerant.

7. OTHER INDUSTRIES

There are other industries such as naval or metallurgical, which rely on refrigeration for their operations or to have a comfortable ambient for their workers to develop their activities. Cooling systems for these industries must be thoroughly designed to avoid short and long terms problems that can result in very high costs of maintenance and operation.

Air conditioning system

INTRODUCTION

➢ Definition - Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favourable conditions.
➢ The control of these conditions may be desirable to maintain the health and comfort of the occupants, or to meet the requirements of industrial processes irrespective of the external climatic conditions.

PRINCIPLES OF AIR-CONDITIONING

The goal is to keep it more comfortable inside the house than it is outside.

TYPE OF AIR-CONDITIONING

1. Window air-conditioning system
2. Split air-conditioning system
3. Centralised air-conditioning system
4. Package air-conditioning system

1) Window air conditioning system

➢ Window air conditioners are one of the most commonly used and cheapest type of air conditioners.
➢ To install one of these units, you need the space to make a slot in the wall, and there should also be some open space behind the wall.
➢ Window air-conditioner units are reliable and simple-to-install solution to keep a room cool while avoiding the costly construction of a central air system.
➢ Better yet, when the summer heat dies down, these units can be easily removed for storage, and you can use the window sill for other purpose

2) Split Air-Conditioning System

➢ The split air conditioner comprises of two parts: the outdoor unit and the indoor unit.
➢ The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve.
➢ The indoor unit comprises the evaporator or cooling coil and the cooling fan. For

this unit you don't have to make any slot in the wall of the room.
➢ Further, the present day split units have aesthetic looks and add to the beauty of the room. The split air conditioner can be used to cool one or two rooms

3) Centralised Air-Conditioning System

➢ The central air conditioning plants or the systems are used when large buildings, hotels, theatres, airports, shopping malls etc. are to be air conditioned completely.
➢ The window and split air conditioners are used for single rooms or small office spaces.
➢ If the whole building is to be cooled it is not economically viable to put window or split air conditioner in each and every room.
➢ Further, these small units cannot satisfactorily cool the large halls, auditoriums, receptions areas etc.

4) Packaged Air-Conditioning System

➢ The window and split air conditioners are usually used for the small air conditioning capacities up to 5 tons.
➢ The central air conditioning systems are used for where the cooling loads extend beyond 20 tons.
➢ The packaged air conditioners are used for the cooling capacities in between these two extremes.
➢ The packaged air conditioners are available in the fixed rated capacities of 3,5, 7, 10 and 15 tons.
➢ These units are used commonly in places like restaurants, telephone exchanges, homes, small halls, etc.

New Invented Technology for Air-Conditioning System

1. DISTRICT COOLING SYSTEM
2. CHILLED BEAM SYSTEM

❖ **District Cooling System**

District Cooling Systems (DCS) is a system which distributes chilled water or other media, usually provided from a dedicated cooling plant, to multiple buildings for air conditioning or other uses.
1. District Cooling System
To centralised production of chilled water by using district cooling plant. The generated chilled water will then be channelled to various building blocks through pre- insulated seamless underground pipes.

Advantages

✓ Improve energy efficiency
✓ Protect environment

✓ Save spaces
✓ Improve urban view
✓ Reduce manpower for operation and maintenance
District Cooling System.

How the System Work?

➢ DC means the centralised production and distribution of cooling energy. Chilled water is delivered via an underground insulated pipeline to office, industrial and residential buildings to cool the indoor air of the buildings within a district.
Specially designed units in each building then use this water to lower the temperature of air passing through the buildings ACS.
➢ The output of one cooling plant is enough to meet the cooling-energy demand of dozens of buildings. DC can be run on electricity or natural gas and can use either regular water or seawater. Along with electricity and water, DC constitute a new form of energy service.

DCS – COMPONENTS

➢ Central Chiller Plant – generate chilled water for cooling purposes.
➢ Distribution Network – distribute chilled water to building.
➢ User Station – interface own building air-conditioning circuit.

2. Chilled beam system

➢ It is a type of convection HVAC system designed to heat or cooled high rise building such as commercial building.
➢ It's primarily gives off its cooling effect through convection by using water to remove heat from a room.
➢ Pipes of water passed through the beam suspended short distance from the ceiling of a room.
➢ As the beam chills the air around it, the air becomes denser and falls to the floor.
➢ It is replaced by warmer air moving up from below, causing a constant flow of convection and cooling the room.

ADVANTAGES

➢ Simple to design and control
➢ Smaller ductwork
➢ Less mechanical space
➢ Less maintenance
➢ Increase comfort

DISADVANTAGES

➢ Not well known in our industry
➢ Higher construction cost
➢ Many engineers aren't familiar with this technology
➢ Dew point concerns, building must have a good control of humidity to prevent condensation on chilled beam surface

THE COOLANT

➢ Heat is removed from the cooling by coolant.
➢ as a heat absorber from the evaporator
➢ Good coolant must have features;
1. Non-toxic
2. Not explosive
3. Non-corrosive components
➢ Not explosive
➢ Soluble in oil to lubricate effectively
➢ Harmless when responding to oil even in the presence of moisture
➢ Have a high resistance to electricity.

Application of Air Conditioning.

Air-conditioning is an important part of human society. Day by day it's the environment that we live-in is in verge of pollution overtake. It's important to us that we breath good conditioned air. Air conditioners have following applications.
1. Air conditioning can be defined as conditioning the air for a natural and comfortable atmosphere within the living area particularly in our home or office.
2. Filtering air for dust particles, mold, insects, and much other microorganism living in air.
3. Employed in large super computer halls to small desktops rooms for keeping them their cool and for their prolonged working.
4. Constant temperature is to be maintained in tool room as you know metal are not so trusted with changing temperature for their dimensions.
5. Air conditioning helps the shop owners for a good sale. Or maybe that is why we hang out in malls more often in college days.
6. Air conditioner maintains the humidity level.
7. Air conditioner can keep your food fresh for a little longer. Sometimes even for 2 years in cold rooms.
8. Air conditioner is used in Operation theatre so that patients could get well soon other than getting his wounds septic due to the microorganisms present in air, which as stated, in a condition without AC.
9. Air conditioning keeps your office toilet smell free its 80% fresh air for every intake air.
10. AC's are used in car and other such vehicle for the comfort of the rider. Aeroplan too.
11. Testing rooms are generally air conditioned.
12. Parking lot needs Air conditioning. That doesn't mean to cool the air but just to circulate the air. A fan specifically exhaust fan will do the work.
13. Air conditioning in airports and bus stand for the comfort of passengers.

Advantages

Most people use air conditioners to stay more comfortable in their homes or offices during hot and humid summer weather. Under extreme conditions, air conditioners may keep elderly and other vulnerable people safer from heat-induced health problems. Air conditioners are used in many commercial settings not only for increased comfort but for decreasing heat stress on delicate machinery such as computers and reducing food spoilage in grocery stores and restaurants.
1. Prevents Dehydration and Heat strokes
Being exposed to excessive heat for long periods can cause dehydration. This is because high temperature leads to profuse sweating and makes your body lose water.
If you fail to replenish this lost water, the result will be dehydration. Since air conditioners reduce sweating, they can minimise the risk of water loss and dehydration.
Heat strokes are another problem that excessive heat can cause. This is because too much heat can make it difficult for the body to regulate its temperature. Failing to treat this problem early enough can cause damage to the brain and other organs of the body. Since air conditioners reduce the temperature of the air, they can be helpful in preventing heat strokes.
2. Improves the Quality of Air
Air conditioners can significantly improve indoor air quality and create a much healthier atmosphere. This is because they are capable of flittering out pollen, dust, and other allergens present in the environment. By reducing humidity, air conditioners can check the growth of mildew and mold.
3. Helps to Reduce Asthma and Allergies
Air conditions can help to filter as well as disinfect the air that we breathe. This can help to reduce the risk of asthma attacks and allergies by removing pollen and dust,

and also preventing the growth of mildew and mold. Being exposed to mold is one of the main factors that increase the risk of asthma attacks, allergic reactions, and other respiratory issues. The fact that we close our windows while using air conditioners helps to prevent the entry of environmental allergens, bacteria, and dust.

Disadvantages

Air conditioners use a lot of electricity. This creates both financial disadvantages for the people who have to pay for the power, and more generalized environmental disadvantages caused by power production. Because a large percentage of electricity is created by coal-burning power plants, air conditioning contributes indirectly to the release of greenhouse gases and other pollutants. In addition, according to The Independent, spending too much time in an air-conditioned environment can contribute to health problems such as asthma, tightness in the chest and other respiratory ailments.

1. Skin Dryness

Spending increased amount of time in an air-conditioned room can make your skin lose its moisture, thereby becoming sensitive and dry. It can also cause irritation and dryness of the mucous membrane.

2. Aggravation of Respiratory Problems

A sudden change in temperature has shown to exacerbate the symptoms of various respiratory diseases. Fortunately, you can significantly reduce the risk of this problem by setting a higher temperature and decreasing it gradually.

3. Respiratory Tract Infections and Allergies

Not cleaning the air conditioner can cause the buildup of dust, bacteria, and pollen in the air filters. This will significantly increase the risk of asthma attacks and respiratory tract infections.

Chapter 8 : Material of Construction

Syllabus:
General study of composition, corrosion, resistance. Properties and applications of the materials of construction with special reference to stainless steel and glass.

A number of equipment are used in the manufacture of pharmaceuticals, bulk drugs, antibiotics, biological products etc. A wide variety of materials are used.

Classification of material of construction:

Materials of construction:-

- Metals
  - Ferrous
    - Cast Iron
    - Steel carbon
    - Stainless Steel
  - Non - ferrous
    - Aluminium
    - Lead
- Non - metals
  - Inorganic
    - Glass
  - Organic
    - Rubber
    - Plastics

FACTORS INFLUENCING THE SELECTION OF MATERIALS OF CONSTRUCTION

The selection of a material for the construction of equipment depends on the following properties

1. Chemical factors
a) Contamination of the product
b) Corrosion of material of construction
2. Physical factors
a) Strength
b) Mass
c) Wear properties
d) Thermal conductivity
e) Thermal expansion
f) Ease of fabrication
g) Cleaning
h) Sterilisation
i) Transparency
3. Economic factors

1. Chemical factors

Whenever a chemical substance is placed in a container or equipment the chemical is exposed to the material of construction of the container or equipment. Therefore, the material of construction may contaminate the product (contamination) or the product may destroy the material of construction (corrosion).

Contamination of product:

Iron contamination may change the color of the products (like gelatin capsule shells), catalyze some reactions that may enhance the rate of decomposition of the product.

Leeching of glass may make aqueous product alkaline. This alkaline medium may catalyze the decomposition of the product.

Heavy metals such as lead, inactivate penicillin.

Corrosion of material of construction:

The products may be corrosive in nature. They may react with the material of construction and may destroy it. The life of the equipment is reduced.

Extreme pH, strong acids, strong alkalis, powerful oxidizing agents, tannins etc. reacts with the materials, hence some alloys having special chemical resistance are used.

2. Physical factors

a) Strength:

The material should have sufficient physical strength to withstand the required pressure and stresses.

• Iron and steel can satisfy these properties. Tablet punching machine, die, upper and lower punch sets are made of stainless steel to withstand the very high pressure.

• Glass, though has strength but are brittle. Aerosol container must withstand very high pressure, so tin plate container coated with some polymers (lacquered) are used.

• Plastic materials are weak so they are used in some packaging materials, like blister packs.

b) Mass:

For transportation light weight packaging materials are used. Plastic, aluminium and paper packaging materials are used for packing pharmaceutical products.

c) Wear properties:

When there is a possibility of friction between two surfaces the softer surface wears off and these materials contaminate the products. For example, during milling and grinding the grinding surfaces may wear off and contaminate the powder. When pharmaceutical products of very high purity is required ceramic and iron grinding surfaces are not used.

d) Thermal conductivity:

In evaporators, dryers, stills and heat exchangers the materials employed have very good thermal conductivity. In this case iron, copper or graphite tubes are used for effective heat transfer.

e) Thermal expansion:

If the material has very high thermal expansion coefficient then as temperature increases the shape of the equipment changes. This produces uneven stresses and may cause fractures. So, such materials should be used those are able to maintain the shape and dimension of the equipment at the working temperature.

f) Ease of fabrication:

During fabrication of an equipment, the materials undergo various processes such as casting, welding, forging and mechanization etc. For example, glass and plastic may be easily moulded in to containers of different shape and sizes. Glass can be used as lining material for reaction vessels.

g) Cleaning:

Smooth and polished surfaces make cleaning easy. After an operation is complete, the equipment is cleaned thoroughly so the previous product cannot contaminate the next product. Glass and stainless-steel surfaces can be smooth and polished, hence are easy to clean.

h) Sterilization:

In the production of parental, ophthalmic and bulk drug products all the equipment is required to be sterilized. This is generally done by introducing steam under high pressure. The materials must withstand this high temperature (1210C) and pressure (15 pounds per square inch). If rubber materials are there it should be vulcanized to withstand the high temperature.

i) Transparency:

In reactors and fomenters, a visual port is provided to observe the progress of the process going on inside the chamber. In this case borosilicate glass is often used.

In parental and ophthalmic containers, the particles, if any, are observed from with polarized light. The walls of the containers must be transparent to see through it.

Here also glass is the preferred material.

3. Economic factors

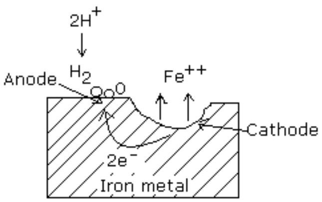
Initial cost of the equipment depends on the material used. Several materials may be suitable for construction from physical and chemical point of view, but from all the materials only the cheapest material is chosen for construction of the equipment.

Materials those require lower maintenance cost are used because in long run it is economical.

CORROSION

Definition: Corrosion is defined as the reaction of a metallic material with its environment,

which causes a measurable change to the material and can result in a functional failure of
the metallic component or of a complete system.
Classification of corrosion according to the environment
1. Dry corrosion: It involves the direct attack of gases and vapor on the metals through
chemical reactions. As a result, an oxide layer is formed over the surface.
2. Wet corrosion: This corrosion involves purely electrochemical reaction, that occurs
when the metal is exposed to an aqueous solution of acid and alkali.
e.g. Zn + 2HCl ZnCl2 + H2↑



THEORY OF CORROSION
1. Corrosion reaction on single metal
A single piece of metal (e.g. Fe) when comes in contact with acid (e.g. HCl) small galvanic
cells may be set up on the surface.
Each galvanic cell consists of (i) anode regions and (ii) cathode regions.
Reaction at anode: Fe on the iron leaves two electrons to the metal and itself becomes
Fe++ ion. Fe++ ion is soluble in water, so it is released in the medium. Thus, the iron surface
is corroded.
Reaction at cathode: The released electron is conducted through the metal piece into
cathode region. Two electrons are supplied to two protons (H+) to form two atoms of H.
Hydrogen atoms are unstable, hence two H atoms will combine to form a molecule of
stable H2. In the absence of acid, water itself dissociates to generate H+ ion.
2H+ + 2e– H2 Hydrogen (H2) forms bubbles on the metal surface. If the
rate of hydrogen formation is very slow then a film of H2 bubbles will be formed that will
slow down the cathode reaction, hence the rate of corrosion will slow down.
If the rate of hydrogen production is very high then hydrogen molecules
cannot form the film on the surface. So, the corrosion proceeds rapidly.
2. Corrosion reactions between metals
If two metals come in contact with a common aqueous medium then one
metal will form anode and the other will form cathode. Now if both the
metals are connected with a wire the reaction will proceed. Anode metal will be corroded
and hydrogen will form at the cathode.
For example, if a zinc and a copper plate is immersed in an acidic medium then zinc will
form anode and will be corroded while hydrogen will be formed at copper plate.
Abode reaction: Zn Zn++ + 2e–.
Cathode reaction: 2H+ + 2e– H2
So, anode will be corroded and hydrogen will be evolved at cathode.

3. Corrosion involving oxygen
The oxygen dissolved in the electrolyte can react with accumulated hydrogen to form
water. Depletion (reduction) of hydrogen layer allows corrosion to proceed.
At cathode: O2 + 2H2 2H2O
The above reaction takes place in acid medium. When the medium is alkaline or neutral
oxygen is absorbed. The presence of moisture promotes corrosion.
FACTORS INFLUENCING CORROSION
1. pH of the solution
• Iron dissolves rapidly in acidic pH.
• Aluminium and zinc dissolves both in acidic and alkaline pH.
• Noble metals are not affected by pH e.g. gold and platinum.
2. Oxidizing agents
Oxidising agents may accelerate the corrosion of one class of materials whereas retard
another class.
• e.g. O2 reacts with H2 to form water. H2 is removed, corrosion is accelerated. Cu in
NaCl solution follows this mechanism.
• e.g. Oxidizing agents forms a surface oxide (like Aluminum oxide) and makes the
surface more resistant to chemical attack.
3. Velocity
When corrosive medium moves at a high velocity along the metallic surface, the rate of
corrosion increases due to:
• Corrosion products are formed rapidly and washed away rapidly to expose new
surface for corrosion reaction.
• Accumulation of insoluble films on the surface is prevented.
• The corrosion is rapid in the bends in the pipes, propellers, agitators and pumps.
4. Surface films
• Thin oxide films are formed on the surface of stainless (rusting). These films absorb

moisture and increases the rate of corrosion.
• Zinc oxide forms porous films. Fluid medium can enter inside and thus corrosion
continues. Nonporous films of chromium oxide or iron oxide prevent corrosion.
• Grease films protect the surface from direct contact with corrosive substances

TYPE OF CORROSION
1. Fluid corrosion: General
When corrosion is generally confined to a metal surface as a whole, it is known as general
corrosion. This corrosion occurs uniformly over the entire exposed surface area. E.g.
Swelling, cracking, softening of plastic materials.
2. Fluid corrosion: Localized
(a) Inter-granular corrosion: During heat treatment or welding, some
components get precipitated at the grain boundary of the metal. These
boundaries acts as anodes and grains as cathodes. So, corrosion of
anode region occurs.
(b) Pitting corrosion: On metal surface small holes or pits are created due to local
corrosion and these pits increase in size rapidly. In the pits the metals dissolves rapidly
especially by chlorine and chloride ions.
(c) Stress corrosion: Certain area of metal may be subjected to thermal, mechanical or
chemical stresses. The surface area becomes anode and acts as corrosion area.
(d) Fretting corrosion: Equipment showing high vibrations destroys the surface of metal
(e.g. steels balls in ball-bearing) by mechanical hitting.
(e) Corrosion fatigue: Cyclic stress breaks the protective film, so corrosion increases.
4. Fluid corrosion: Biological
Metabolic action of microorganisms can either directly or indirectly cause deterioration
of a metal by:
(i) Creating electrolyte concentration cells on the metal surface.
(ii) Influence the rate of anodic / catholic reactions.
(iii) Sulphates are reduced by reducing bacteria and produces hydrogen peroxide (H2S)
that reacts with iron to produce ferrous sulphide (FeS). Thus, the iron gets
corroded.
PREVENTION OF CORROSION
Following methods may be adopted for preventing or reducing corrosion:
1. Material selection
(a) Pure materials have less tendency towards pitting, but they are expensive and soft.
Therefore, only aluminium can be used in pure form.
(b) Improved corrosion resistance can be obtained by adding corrosion resistant
elements. For example, intergranular corrosion occurs in stainless steel. This tendency
can be reduced by addition of small amount of titanium.
(c) Nickel, copper and their alloys are used in non-oxidizing environment, whereas
chromium containing alloys are used in oxidizing environment.
(d) Materials those are close in electrochemical series should be used for fabrication.
(e) Corrosive materials are taken with suitable material of construction:

Corrosive material	Suitable material
Nitric acid	Stainless steel
Hydrofluoric acid	Monel metal
Distilled Water	Tin
Dilute Sulfuric acid	Lead
Caustic	Nickel

3. Proper design of equipment
Corrosion can be minimized in the following conditions:
(a) Design for complete drainage of liquids.
(b) Design for ease of cleaning.
(c) Design for ease of inspection and maintenance
(d) A direct contact between two metals should be avoided. They may be insulated
from one another.
4. Coating or lining
Corrosion resistant coating may be applied on metal surface to improve corrosion
resistance. It also separates the metal from corrosive environment.
(a) Organic coating is used as lining in equipment such as tanks, & piping.
FERROUS MATERIAL
Cast Iron, Steels, Stainless Steels
❖ Cast Iron
This iron consists of carbon more than 1.5%. Different proportions of carbon give different
properties of the steel.
Properties:
1. Cast iron is resistant to concentrated sulfuric acid, nitric acid and dilute alkalis.
2. Cast iron is attacked by dilute sulfuric acid, dilute nitric acid and dilute and

concentrated hydrochloric acid.
3. Cast iron has low thermal conductivity.
4. It is not corrosion resistance hence it is alloyed with Silicon, Nickel or Chromium to produce corrosion resistance.
5. It is brittle so it is tough to machine.

Applications:
1. It is used as supports for plants.
2. Thermal conductivity is low hence used as the outer wall of steam jacket.
3. It is cheap hence used in place of more expensive materials by coating with enamel or plastic.

❖ **Carbon Steel or Mild Steel**
Mild steel (or carbon steel) is an iron alloy that contains a small percentage of carbon (less than 1.5%).
Properties
1. It has greater mechanical strength than cast iron.
2. It is easily weldable.
3. Has limited resistance to corrosion. This property can be increased by proper alloying.
4. It reacts with caustic soda, brine (concentrated NaCl solution).

Applications
1. Used for construction of bars, pipes and plates.
2. Used to fabricate large storage tanks for water, sulfuric acid, organic solvents etc.
3. Used as the supporting structures of grinders and bases of vessels.

❖ **Stainless Steel**
Stainless steel is an alloy of iron usually of nickel and chromium.
For pharmaceutical use stainless steel contains 18% chromium and 8% nickel. This steel is called 18/8 stainless steel.
In addition to corrosion resistance, the advantageous physical properties of stainless steel include:
1. It is heat resistant
2. Corrosion resistant
3. Ease of fabrication
4. Cleaning and sterilization is easy.
5. Has good tensile strength.
6. High and low temperature resistance.
7. Ease of fabrication.
8. High Strength.
9. Aesthetic appeal.
10. Hygiene and ease of cleaning.
11. Long life cycle.
12. Recyclable.
13. Low magnetic permeability.
14. During heat welding the corrosion resistant properties of stainless steel may be reduced due to deposition of carbide precipitate at the crystal grain boundaries.
This steel is stabilized by addition of minor quantities of titanium, molybdenum or niobium.
Applications:
Stainless steel applications

1. Automotive and transportation
Stainless steel was introduced in automotive in the 1930s by Ford to manufacture their concept cars. Since then, it is used to produce a variety of automotive parts such as exhaust systems, grills, and trims. With advancing technology, stainless steel is being favoured by manufacturers to make structural components.
It is also heavily featured in other fields of transportation like freighting to make shipping containers, road tankers and refuse vehicles. It's resistance to corrosion makes it ideal to transport chemicals, liquids and food products. The low maintenance of stainless steel also makes it an easy and cost-effective metal to clean and sustain.

2. Medical technology
Stainless steel is preferred in clean and sterile environments as it is simple to clean and does not easily corrode. Stainless is used in the production of a wide range of medical equipment, including surgical and dental instruments. It is also used in building operation tables, kidney dishes, MRI scanners, cannulas, and steam sterilizers. Most surgical implants, such as replacement joints and artificial hips are made from stainless steel, as well as some joining equipment like stainless steel pins and plates to repair broken bones.

3. Building trade
Due to its strength, resistance, and flexibility, stainless steel application has become a vital element of the building trade. It is commonly featured in the interior on countertops, backsplashes, and handrails, and is also used externally in cladding for high impact buildings. It is a common feature in modern architecture due to its weldability, easy maintenance and attractive finish, which is used in the Eurostar Terminal in London and the Helix Bridge in Singapore. With the movement towards sustainable building, stainless steel, which is a highly recyclable metal, is becoming increasingly preferable to use in

construction. With a polished or grain finish, it has aesthetically pleasing properties and can aid in improving natural lighting in the building.

4. Aircraft Construction
The aviation industry also has a preference for stainless steel. It is used in various applications including the frames of aero planes because of its strength and ability to withstand extreme temperatures. It can also be applied in jet engines as it can help prevent against its rushing Stainless steel is also an essential part of the landing gear. Its strength and rigidity can handle the weight of the landing aircraft.

5. Food and the catering industry
In the food and catering industry, stainless steel is used to manufacture kitchen accessories, cookware, and cutlery. Utensils such as knives are made using less ductile grades of stainless steel. The more ductile grades are used to make grills, cookers, saucepans, and sinks. Stainless steel can also be used to finish freezers, dishwashers, refrigerators, and countertops. In food production, stainless steel is ideal because it doesn't affect the flavour of the food. It is also corrosion resistant, and hence able to hold acidic drinks including orange juice. The ease of cleaning stainless steel makes it difficult to harbour bacteria, adding to its usefulness in food storage.
6. Tanker manufacture
7. Vessel manufacture

❖ Aluminum
Properties:
1. Pure aluminium is soft and more corrosion resistant than its alloys. Small percentages of manganese, magnesium or silicon produces strong, corrosion resistant aluminium alloys (e.g. Duralumin)
2. It is attacked by mineral acids, alkali, mercury and its salts.
3. It is resistant to strong nitric acid.
4. It is resistant to acetic acid due to the formation of a gelatinous surface film of aluminium sub acetate.
5. Low density hence lighter.
Applications:
1. The salts of aluminium is colourless and non-toxic to microorganisms, hence used for fermenting vessels for biosynthetic production of citric acid, gluconic acids and streptomycin.
2. Used for making extraction and absorption vessels in preparation of antibiotics.
3. Storage vessels of acetic acid and ammonia.
4. Plants for nitric acid is used.
5. Because of its lightness large containers such as drums, barrels, road and rail tankers are made with aluminium.

GLASS
Preparation of glass:
Glass is composed principally of sand (silica - SiO_2), soda-ash (Na_2CO_3 - sodium carbonate) and lime-stone ($CaCO_3$-calcium carbonate).
Glass made from pure silica consists of a three-dimensional network of silicon atoms each of which is surrounded by four oxygen atoms an in this way the tetrahedral are linked together to produce the network.
Glass prepared from pure silica require very high temperature to fuse, hence soda-ash and lime is used to reduce the melting point.
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(i) glass made of pure silica has network (Fig-1)
Properties:
(a) It is very hard and
(b) chemically resistant but
(c) melting point very high so it is very difficult to mould.
(ii) Glass made of pure silica + Na_2O (Fig.-2)
(valency of Na = 1)
Properties:
(a)Structure is less rigid so low m.p. and easier to mould
(b) the glass is too rapidly attacked by water and NaOH is leached out of the glass.
(iii) Pure silica + CaO (or BaO, MgO, PbO and ZnO) (Fig.-3)
(valency of Ca, Ba, Mg, Pb, Zn = 2)
Properties:
(a) divalent oxides do not break the network of pure silica, but only push the tetrahedron apart. It is more rigid than soda-silica network.
(b) Since the bond is more stronger, hence chemical reactivity is lowered.

(iv) Pure silica + Boric(B_2O_3) or aluminium oxide (Al_2O_3)
(valency of B and Al = 3, i.e. trivalent)
Properties:
(a) Since boric oxide, like silica, is acidic. it does not disrupt the network of silica but forms tetrahedron itself; however, these are not the same size as the silicon tetrahedral; as a result, the lattice become distorted, and this produces flexibility.
(b) It is chemically resistant.

Types of glass	Main constituents	Properties	Uses
Type-1 Borosilicate glass e.g. Pyrex, Borosil	SiO_2 80% B_2O_3 12 Al_2O_3 - 2% Na_2O+CaO - 6%	• Has high melting point so can withstand high temperature • Resistant to chemical substances • Reduced leaching action	• Laboratory glass apparatus • For injections and • for water for injection.
Type-II Treated soda-lime glass	Made of soda lime glass. The surface of which is treated with acidic gas like SO_2 (i.e. dealkalizer) at elevated temperature (5000C) and moisture.	• The surface of the glass is fairly resistant to attack by water for a period of time. • Sulfur treatment neutralizes the alkaline oxides on the surface, thereby rendering the glass more chemically resistant.	• Used for alkali sensitive products • Infusion fluids, blood & plasma. • large volume container
Type-III Regular soda-lime glass	SiO_2 Na_2O CaO	• It contains high concentration of alkaline oxides and imparts alkalinity to aqueous substances • Flakes separate easily. • May crack due to sudden change of temperature.	• For all solid dosage forms (e.g. tablets, powders) • For oily injections • Not to be used for aqueous injection • Not to be used for alkali-sensitive drugs.
Type NP Non-parenteral glass or General-purpose soda-lime glass.			• For oral and • Topical purpose • Not for ampoules.
Neutral Glass	SiO_2 72-75% B_2O_3 7-10% Al_2O_3 6% Na_2O 6-8% K_2O 0.5 2% BaO 2-4%	They are softer and can easily be moulded • Good resistance to autoclaving • Resistant to alkali preparations • Lower cost than borosilicate	Small vials (<25 ml) • Large transfusion bottles
Neutral Tubing for Ampoules	SiO_2 67% B_2O_3 7.5% Al_2O_3 8.5% Na_2O 8.7% K_2O 4% CaO 4% MgO 0.3%	• In comparison to neutral glass its melting point is less. After filling the glass ampoules are sealed by fusion and therefore the glass must be easy to melt.	• Ampoules for injection.
Colored glass	Glass + iron oxide	• Produce amber colour glass • Can resist radiation from 290 400 450 nm UV -Visible	• For photosensitive products.

Advantages of glass container
Physical aspect
1. They are quite strong and rigid.
2. They are transparent which allows the visual inspection of the contents; especially in ampoules and vials.
3. They are available in various shapes and sizes. Visually elegant containers attract the patients.
4. Borosilicate (Type-I) and Neutral glasses are resistant to heat so they can be readily sterilized by heat.
5. Glass containers can be easily cleaned without any damage to its surface e.g. scratching or bruising.

Chemical aspect
1. Borosilicate type of glass is chemically inert. Treated soda lime glass has a chemically inert surface.
2. As the composition of glass may be varied by changing the ratio of various glass constituents the proper container according to desired qualities can be produced.
3. They do not deteriorate with age, if provided with proper closures
4. Photosensitive drugs may be saved from UV-rays by using amber color glass.

Economical aspect
1. They are cheaper than other packaging materials.

Disadvantages:
Physical aspect
1. They are brittle and break easily.
2. They may crack when subject to sudden changes of temperatures.
3. They are heavier in comparison to plastic containers.
4. Transparent glasses give passage to UV-light which may damage the photosensitive drugs inside the container.

Chemical aspect
1. Flaking: From simple soda-lime glass the alkali is extracted from the surface of the container and a silicate rich layer is formed which sometimes gets detached from the surface and can be seen in the contents in the form of shining plates known as ‘flakes’ and in the form of needles they are known as ‘spicules’. this is a serious problem, especially in parenteral preparations.
2. Weathering: Sometimes moisture is condensed on the surface of glass container which can extract some weakly bound alkali leaving behind a white deposit of alkali carbonate to remain over there, further condensation of moisture will lead to the formation of an alkaline solution which will dissolve some silica resulting in loss of brilliance from the surface of glass called weathering.
To prevent weathering, the deposited white layer of alkali carbonates should be removed as early as possible by washing the containers with dilute solution of acid and then washing thoroughly with water.