# BASIC CIVIL AND MECHANICAL ENGINEERING

## PART-A: 23AES0101

## UNIT-1

**INTRODUCTION:**

Civil Engineering is the field of engineering concerned with planning, design and construction for environmental control, development of natural resources, buildings, transportation facilities and other structures required for health, welfare, safety, employment and pleasure of mankind. The main scope of civil engineering or the task of civil engineering is planning, designing, estimating, supervising construction, execution, and maintenance of structures like building, roads, bridges, dams, etc. Population demographics along with increasing urbanization have facilitated the need for sustainable and efficient infrastructure solutions. Development in green buildings, sensor-embedded roads and buildings, geopolymer concrete, and water management will stimulate global civil engineering industry growth.

**Role of Civil engineer in the society:**

Civil engineers play a crucial role in society by designing, planning, and managing infrastructure and construction projects that have a significant impact on the well-being and development of communities. Their responsibilities encompass a wide range of tasks and functions, including:

a. Infrastructure Development: Civil engineers are responsible for designing, constructing, and maintaining critical infrastructure such as roads, bridges, tunnels, airports, and railways. These systems are essential for the transportation of goods and people, which is fundamental for economic development.
b. Water Resources Management: Civil engineers are involved in the planning and management of water supply, treatment, and distribution systems. They also work on wastewater treatment and storm- water management to ensure clean and reliable water resources for communities.
c. Building and Structural Design: Civil engineers design and oversee the construction of various structures, including buildings, dams, and stadiums. Their work ensures that these structures are safe, durable, and meet the requirements of local building codes.
d. Environmental Engineering: Civil engineers work on projects related to environmental protection, such as designing systems to control air and water pollution, waste management, and sustainable infrastructure development to minimize the impact on the environment.
e. Geotechnical Engineering: They study the properties of soil and rock to determine their suitability for construction. This is vital to ensure the stability and safety of structures.
f. Transportation Engineering: Civil engineers design and manage transportation systems to optimize traffic flow, reduce congestion, and improve safety. They also focus on developing sustainable and efficient modes of transportation.
g. Project Management: Civil engineers are often responsible for overseeing the planning, execution, and completion of construction projects. This involves managing budgets, schedules, and resources to ensure projects are delivered on time and within budget.
h. Innovative Technologies: They stay updated on emerging technologies, such as 3D printing, drones, and smart materials, to apply them in construction and infrastructure projects to enhance efficiency and sustainability.
i.

**Field Of Civil Engineering:**

Civil engineering is a wide field and includes many types of structures such as residential buildings, public buildings, industrial buildings, roads, bridges, tunnels, railways, dams, canal and canal structures, airports, harbours, ports, water treatment plants, waste water treatment plants, water supply networks, and drainage networks. It also covers environmental protection, irrigation and water resources, soil investigations and foundations, transport systems management, etc.

**Disciplines In Civil Engineering:**

a. Structural Engineering: Scope: Structural engineers design and analyze the structural components of buildings, bridges, dams, and other structures to ensure they are safe and can withstand various loads and environmental conditions. They work with materials like concrete, steel, and timber.
b. Geotechnical Engineering: Scope: Geotechnical engineers study the properties of soil and rock to assess their suitability for construction. They provide recommendations for foundations, earth retention systems, and slope stability to ensure the stability and safety of structures.
c. Transportation Engineering: Scope: Transportation engineers focus on planning, designing, and managing transportation systems. They work on roads, highways, railways, airports, and public transit systems to optimize traffic flow, safety, and efficiency.
d. Environmental Engineering: Scope: Environmental engineers address issues related to the protection and preservation of the environment. They design systems for water and wastewater treatment, manage air quality, and develop strategies for waste disposal and recycling.
e. Water Resources Engineering: Scope: Water resources engineers work on the planning, design, and management of water supply and distribution systems, as well as flood control and storm-water management. They ensure the sustainable use of water resources.
f. Construction Management: Scope: Construction managers oversee all aspects of construction projects, from planning and budgeting to scheduling and quality control. They ensure that projects are completed on time and within budget while meeting safety and quality standards.
g. Urban Planning and Design: Scope: Urban planners and designers work on the layout and organization of cities and urban areas. They consider land use, zoning, transportation, and public spaces to create sustainable, livable, and aesthetically pleasing environments.
h. Remote Sensing and GIS: Scope: Civil engineers use remote sensing and Geographic Information Systems (GIS) to gather and analyze spatial data for planning, designing, and managing infrastructure projects, including land use planning and environmental monitoring.

**Process Of Building Planning And Construction:**

Construction planning is the specific process a construction manager uses to lay out how they will manage and execute a construction project, from building design to completion.

STEP 1: INITIATE THE PROJECT: Start by creating a project initiation document (PID),

People: Number of workers needed, including contractors and subcontractors such as plumbers and electricians.

Resources: Materials needed for the design and building plans.

Budget: Total cost estimate of the project, including labor, materials, equipment, fees, and permits.

STEP 2: CREATE THE PROJECT PLAN:

Specific: Set specific goals for your project, such as deadlines for key milestones.

Measurable: Agree on how you will measure success for goals. For example, is it good enough that you have started laying concrete by the deadline you set, or should it be completely set by that date.

Attainable: You need to have a plan in place for how you're going to achieve these goals. For example, does your project depend on a specific material that might not be available in the quantity you need when you need it? If so, you need to make adjustments.

STEP 3: EXECUTE THE PLAN: Begin by creating a high level project timeline, including major milestones and key deliverables, to keep everything on track. Once you have a timeline in place, start mapping out the details of each project stage.

STEP 4: TRACK PROJECT PROGRESS

Project objectives: Are you on schedule and budget?

Project performance: Is the project proceeding smoothly, or are you running into some obstacles you weren't expecting?

Quality: Sure, the crew is hitting their milestones, but is the work up to the quality that you want at this stage?

STEP 5: CLOSE OUT AND EVALUATE THE PROJECT:

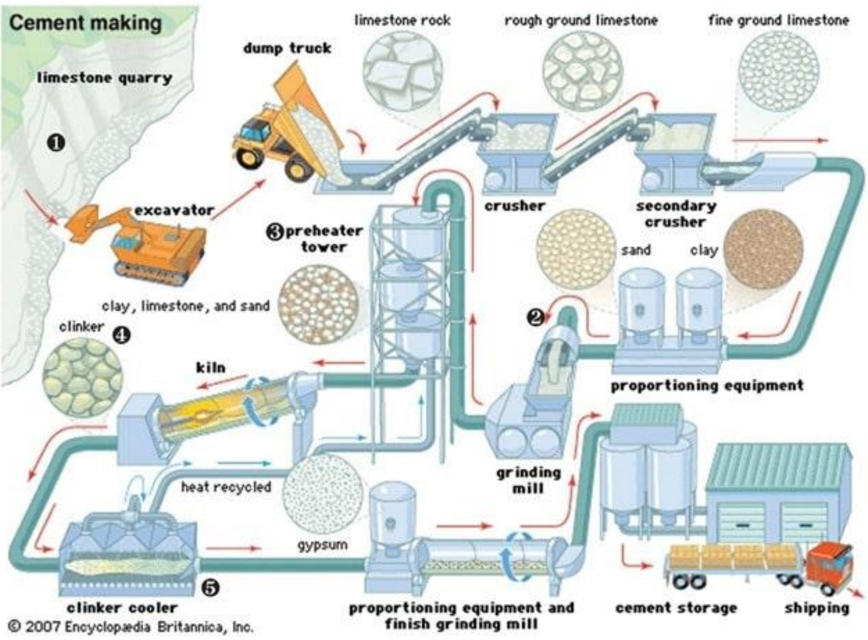
Evaluate your current construction software. Does it offer the features discussed above? If not, it may be time to start examining options that do. Compare solutions and read user reviews, or check out construction software buyers guides for more help.

Create a mock project initiation document, and ask yourself some questions: Have I been going into this level of detail before a project? How can it help me? How can I incorporate this into my next project?

Examine your current work schedule. Where can you schedule time to conduct an extensive planning process that incorporates all of these steps? Be intentional and carve out some time to do it because it's very easy to allow your time to get swallowed up by day-to-day tasks or emergencies.

**Manufacturing And Applications Of Cement:**

Manufacturing of cement involves various raw materials and processes. Each process is explained chemical reactions for manufacture of Portland Cement. Cement is a greenish grey colored powder, made of calcined mixtures of clay and limestone. When mixed with water becomes a hard and strong building material.




The manufacture procedures of Portland cement is described below.

1. Mixing of raw material
2. Burning
3. Grinding
4. Storage and packaging

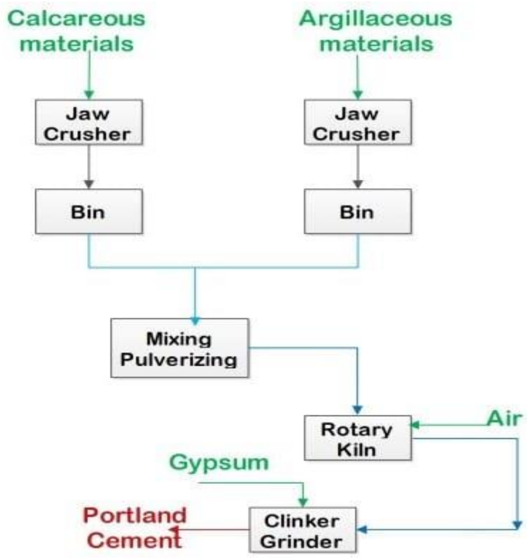
1**. Mixing of raw material**: The major raw materials used in the manufacture of cement are Calcium, Silicon, Iron and Aluminum. These minerals are used in different form as per the availability of the minerals. Table shows the raw materials for Portland cement manufactureraw-material-for-cement-manufacture.

| Calcareous Materials | Argillaceous Materials | | |
|---|---|---|---|
| **Calcium** | **Silicon** | **Aluminum** | **Iron** |
| Limestone | Clay | Clay | Clay |
| Marl | Marl | Shale | Iron ore |
| Calcite | Sand | Fly ash | Mill scale |
| Aragonite | Shale | Aluminum ore refuse | Shale |
| Shale | Fly ash | | Blast furnace dust |
| Sea Shells | Rice hull ash | | |
| Cement kiln dust | Slag | | |

The mixing procedure of the manufacture of cement is done in 2 methods,
Dry process
Wet process

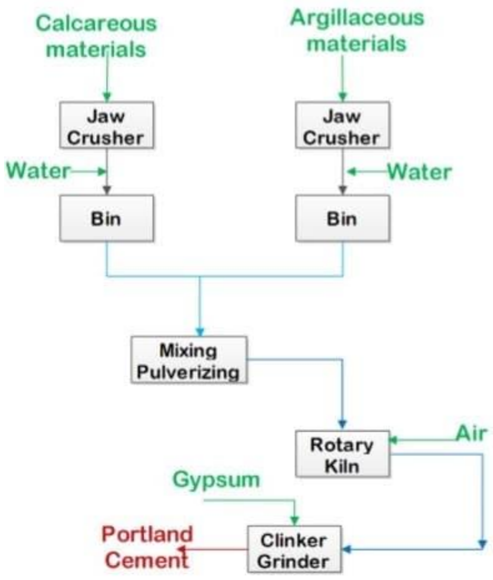
a) **Dry Process**

The both calcareous and argillaceous raw materials are firstly crushed in the gyratory crushers to get 2-5cm size pieces separately. The crushed materials are again grinded to get fine particles into ball or tube mill. Each finely grinded material is stored in hopper after screening. Now these powdered minerals are mixed in required proportion to get dry raw mix which is then stored in silos and kept ready to be sent into rotary kiln. Now the raw materials are mixed in specific proportions so that the average composition of the final product is maintained properly.




**b) Wet Process**

The raw materials are firstly crushed and made into powdered form and stored in silos. The clay is then washed in washing mills to remove adhering organic matters found in clay. The powdered limestone and water washed clay are sent to flow in the channels and transfer to grinding mills where they are completely mixed and the paste is formed, i.e., known as slurry. The grinding process can be done in ball or tube mill or even both. Then the slurry is led into collecting basin where composition can be adjusted. The slurry contains around 38-40% water that is stored in storage tanks and kept ready for the rotary kiln.




The burning process is carried out in the rotary kiln while the raw materials are rotated at 1-2rpm at its longitudinal axis. The kiln is heated with the help of powdered coal or oil or hot gases from the lower end of the kiln so that the long hot flames is produced. As the kiln position is inclined and it rotates slowly, the material charged from upper end moves towards lower end at the speed of 15m/hr. In the upper part, water or moisture in the material is evaporated at 400oC temp, so this process is known as Drying Zone. The central part i.e. calcination zone, the temperature is around 10000C, where decomposition of lime stone takes place. The remaining material is in the form of small lumps known as nodules after the CO2 is released.

$$CaCO3 = CaO + CO2$$

The lower part (clinkering zone) have temperature in between 1500-17000C where lime and clay are reacts to yielding calcium aluminates and calcium silicates. These aluminates and silicates of calcium fuse to gather to form small and hard stones are known as clinkers. The size of the clinker is varies from 5-10mm.

The clinker coming from the burning zone are very hot. To bring down the temperature of clinkers, air is admitted in counter current direction at the base of the rotary kiln. The cooled clinkers are collected in small trolleys.

**Grinding of Clinkers**

The cooled clinkers are received from the cooling pans and sent into mills. The clinkers are grinded finely into powder in ball mill or tube mill. Powdered gypsum is added around 2-3% as retarding agent during final grinding. The final obtained product is cement that does not settle quickly when comes in contact with water.

**Storage and packaging**

The grinded cement is stored in silos, from which it is marketed either in container load or 50kg bags.

**Applications of Cement**

Cement is mainly used as a binder in concrete, which is a basic material for all types of construction, including housing, roads, schools, hospitals, dams and ports, as well as for decorative applications (for patios, floors, staircases, driveways, pool decks) and items like tables, sculptures or bookcases.

**Manufacturing And Applications of Bricks:**

Bricks play a primary role in construction at all levels beginning from thatched roofs to multi-storeyed buildings. Over many years, the process of brick making has not changed except for minor refinements. Bricks are the oldest construction material which has been broadly used at present due to its durability, availability and low cost. Refined brick making and burning techniques have exceptionally improved the quality of buildings.

Manufacturing of bricks constitutes four stages i.e., preparation of soil, moulding, drying and burning.
Preparation of Soil

**Removal of Top Soil:** The removal of top soil involves the loose materials present at the top of the soil for a depth of about 200 mm. These materials should be removed as they contain a lot of **impurities** and are not used in the preparation of bricks.

**Digging and Spreading**: After digging the soil for about 200 mm, the soil is spread on the level ground, and the heaps of clay are about 600 to 1200 mm.

**Cleaning:** After spreading the soil on the ground, it should be cleaned of stones, vegetable matter, pebbles, etc... If excess non-clay materials are present, the clay should be washed and screened. This whole process will become expensive and clumsy. The lumps in soil should be crushed into a powder form.

**Weathering:** The soil is then exposed to the atmosphere for softening for a few weeks depending on the nature of the soil, which imparts plasticity and strength to the soil.

**Blending:** To increase the quality of soil, additionally, sandy or calcareous clays may be added in suitable proportions along with coal, ash, etc. and the whole mass is mixed uniformly with water.

**Tempering**: After adding the sufficient quantity of water, the soil is kneaded under the feet of men or cattle to make it stiff and homogeneous. In general, for handmade bricks, the soft plastic clay could be prepared by using about 25 to 30 per cent water. For making superior bricks on a large scale of about 20,000, the earth is tempered in a pug mill.

**Moulding of Bricks**

Bricks are made in metric sizes called modular bricks, as prescribed by the Bureau of Indian Standards. Nominal size of the bricks is 20cm X 10cm X 10cm, which include the thickness of the mortar and the actual size of modular brick is 19cm X 9cm X 9cm.

A brick mould is a rectangular box of steel or wood, which is open at the top and bottom of the box and inside dimensions of the mould are 20cm X 10cm X 10cm.

Moulding of bricks can be done using either hand or machine.

**Hand Moulding**

There are two types in hand moulding, i.e. ground moulding and table moulding. In this type, bricks are moulded manually and preferred where only a small quantity of bricks is needed.

**Ground Moulding:** The process of moulding bricks on the ground manually by labour is called ground moulding. On an average, a moulder can mould about 750 bricks per day. When the bricks have dried sufficiently, they are moved to the drying shed and placed in an orderly manner.

**Table Moulding:** This moulding is done on a table of size 2m X 1m X 0.7m instead of on the ground. This table moulding process is almost similar to ground moulding expect for some minor changes.

Machine Moulding: Moulding machines are used when a large scale of bricks are to be manufactured in less time. These types of bricks are heavier and stronger than the hand moulded ones and possess a sharp regular shape, a smoother surface and sharp edges. There are two types in machine moulding.

**Plastic Method:** In this method, pugged earth is used, which is placed in the machine that contains a rectangular shape of size equal to the length and width of the brick. A beam of the moulded earth comes out of it and is cut into strips by wires fixed in the frames. These bricks are also called wire-cut bricks.

**Dry Method:** In this method, the machine first converts the hard earth into a powder form and a small quantity of water is added to the powder to make it a stiff plastic paste. This paste is placed in the mould and pressed by the machine to form hard and correct-shaped bricks. These bricks are known as pressed bricks, which do not require any **drying** and can be sent directly to the burning section.

Drying of Bricks: Moulded bricks cannot be burnt directly, as they may get damaged. So before burning they should be dried either naturally or artificially for about two weeks.

**Natural Drying:** It is also called hack drying, which comprises placing moulded bricks in rows on their edges, slightly above the ground called a hack. These bricks are air and sun-dried that is strong enough to use for the construction of small structures.

**Artificial Drying:** When bricks are needed to dry on a large scale, then this artificial drying is preferred. They are dried in special dryers which receive heat from specially made furnaces for artificial drying.

Burning of Bricks: After the process of moulding and drying, bricks are burnt in kilns to impart hardness, strength and to increase the density of the brick. Some physical and chemical changes take place in the burning of bricks. Heating brick to about 640°C produces only physical changes. If a brick is heated up to 700-1,000°C, it undergoes chemical changes. During this reaction, the materials present in brick alumina and silica fuse together to make the brick strong and stable to prevent from cracking and crumbling.

The types of Kilns used for burning purposes are

**Clamp or Open Kiln:** This is a temporary structure with some advantages like low initial cost, low fuel cost and a few skilled laborers are sufficient to complete the process. The disadvantage is only a small quantity of bricks is manufactured at a time and in that only **60% are good quality bricks**.

**Intermittent Kiln:** When a large number of good quality bricks are needed, intermittent or continuous kilns are preferred. In this kilns, the process of burning is discontinuous.

**Continuous Kilns:** In this process, the burning is continuous and they are of three type's i.e., **Bull's Trench Kiln, tunnel Kiln and Hoffman's Kiln.**

**Applications of Bricks**

- Construction of walls of any size.
- Construction of floors.
- Construction of arches and cornices.
- Construction of brick retaining wall.

## CEMENT CONCRETE:

Concrete is a composite material made from a mixture of water, cement, and aggregates like sand, gravel, or crushed stone.

**Proportion of cement, sand and coarse aggregates in concrete**

| *S. No.* | *Proportion* | *Nature of Work* |
|---|---|---|
| 1 | 1:1:2 | For machine foundation, footings for steel columns and concreting under water. |
| 2 | $1:1\frac{1}{2}:3$ | Water tanks, shells and folded plates, for other water retaining structures. |
| 3 | 1:2:4 | Commonly used for reinforced concrete works like beams, slabs, tunnel lining, bridges |
| 4 | 1:3:6 | Piers, abutments, concrete walls, sill of windows, floors. |
| 5 | 1:4:8 | Mass concretes like dam, foundation course for walls, for making concrete blocks. |

**Preparing and Placing of Concrete:**

1. Batching
2. Mixing
3. Transporting and placing and
4. Compacting.

**Batching:** The measurement of materials for making concrete is known as batching. The following two methods of batching is practiced: (a) Volume batching (b) Weight batching.

**Mixing:** To produce uniform and good concrete, it is necessary to mix cement, sand and coarse aggregate, first in dry condition and then in wet condition after adding water. The following methods are practiced: (a) Hand Mixing (b) Machine Mixing.

**Transporting and Placing of Concrete.** After mixing concrete should be transported to the final position. In small works it is transported in iron pans from hand to hand of a set of workers

**Compaction of Concrete:** In the process of placing concrete, air is entrapped. The entrapped air reduces the strength of concrete up to 30%.

**CURING OF CONCRETE**

Curing in the early ages of concrete is more important. Curing for 14 days is very important. Better to continue it for 7 to 14 days more. If curing is not done properly, the strength of concrete reduces. Cracks develop due shrinkage. The durability of concrete structure reduces. The following curing methods are employed:

(a) Spraying of water

(b) Covering the surface with wet gunny bags, straw etc.

(c) Ponding

(d) Steam curing and

(e) Application of curing compounds

**PROPERTIES OF CONCRETE:**

Concrete has completely different properties when it is the plastic stage and when hardened. Concrete in the plastic stage is also known as green concrete. The properties of green concrete include:

1. Workability
2. Segregation
3. Bleeding
4. Harshness.

The properties of hardened concrete are:

1. Strength
2. Resistance to wear
3. Dimensional changes
4. Durability
5. Impermeability.

**TESTS ON CONCRETE**

The following are some of the important tests conducted on concrete:

1. Slump test.
2. Compaction factor test.
3. Crushing strength test.

**USES OF CONCRETE**

1. As bed concrete below column footings, wall footings, on wall at supports to beams
2. As sill concrete
3. Over the parapet walls as coping concrete
4. For flagging the area around buildings
5. For pavements
6. For making building blocks.

**TYPES OF CONCRETE**

- Light-weight concrete
- High-density concrete
- Polymer concrete
- Fibre-reinforced concrete

## BRICK:

The common brick is one of the oldest building materials and it is extensively used at present because of its durability, strength, reliability, low cost, etc. Bricks are obtained by moulding clay in rectangular blocks of uniform size, then by drying and burning these blocks in brick kilns.

**Qualities of good Bricks:**

1. Bricks should have perfect edges, well-burnt in kilns, copper coloured, free from cracks with proper rectangular shape and of standard size (19 × 9 × 9 cm).
2. Bricks should give a clear ringing sound when struck with each other.
3. Bricks must be homogeneous and free from voids.
4. The percentage absorption of water by weight should not be greater than 20 per cent for first-class bricks and 22 per cent for second-class bricks when soaked in cold water for 24 hours.
5. Bricks should be sufficiently hard, i.e., no nail impression must be present when scratched. The average weight of bricks should be 3–3.5 kg.
6. Bricks should not break when dropped from a height of 1 m.
7. Bricks should have low thermal conductivity and should be soundproof.
8. Bricks should not show deposits of salts when immersed in water and dried.
9. The minimum crushing strength of bricks must be 3.5 $N/mm^2$

**Classification of Bricks:**

**First Class Bricks:**

These bricks are table moulded and of standard shape and they are burnt in kilns. The surface and edges of the bricks are sharp, square, smooth and straight. They comply with all the qualities of good bricks. These bricks are used for superior work of permanent nature.

**Second Class Bricks:**

These bricks are ground moulded and they are burnt in kilns. The surface of these bricks is somewhat rough and shape is also slightly irregular. These bricks may have hair cracks and their edges may not be sharp and uniform. These bricks are commonly used at places where brick work is to be provided with a coat of plaster.

**Third Class Bricks:**

These bricks are ground moulded and they are burnt in clamps. These bricks are not hard and they have rough surfaces with irregular and distorted edges. These bricks give dull sound when struck together. They are used for unimportant and temporary structures and at places where rainfall is not heavy.

**Fourth Class Bricks:**

These are over burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundations, floors, roads etc, because of the fact that the over burnt bricks have a compact structure and hence they are sometimes found to be stronger than even the first class bricks.

**Tests on Bricks:**

- Compressive strength test
- Water Absorption test
- Efflorescence test
- Hardness test
- Size, Shape and Colour test
- Soundness test
- Structure test

**Constituents of a Brick:**

- Alumina (20-30%): imparts plasticity to the earth.
- Silica (50-60%): prevents cracking, shrinking and warping of raw bricks. Imparts uniform shape to bricks.
- Lime (5%): prevents shrinkage
- Oxide of iron (5%): red colour to bricks
- Magnesia: imparts yellow tints to bricks and it reduces shrinkage

## STEEL:

It is extensively used building material. The following three varieties of steel are extensively used:

(a) Mild steel

(b) High carbon steel and

(c) High tensile steel.

**(a) Mild Steel:** It contains a maximum of 0.25% carbon, 0.055% of sulphur and 0.55% of phosphorus.

**Properties of Mild Steel:**

(i) It is malleable and ductile

(ii) It is more elastic

(iii) It can be magnetized permanently.

(iv) Its specific gravity is 7.8.

(v) Its Young's modulus is 2.1 × 105 N/mm2.

(vi) It can be welded easily.

(vii) It is equally strong in tension and in compression.

**Uses of Mild Steel:**

(i) Round bars are extensively used as reinforcement in R.C.C. works.

(ii) Rolled sections like I, T, L, C, plates etc. are used to build steel columns, beams, trusses etc.

(iii) Tubular sections are used as poles and members of trusses.

(iv) Plain and corrugated mild steel are used as roofing materials.

(v) Mild steel sections are used in making parts of many machineries.

**(b) High Carbon Steel:** The carbon contains in this steel is 0.7% to 1.5%.

**Properties of Carbon Steel:**

(i) It is more tough and elastic compared to mild steel.

(ii) Welding is difficult.

(iii) It can be magnetized permanently.

(iv) It is stronger in compression than in tension.

(v) It withstands shocks and vibrations better.

**Uses of High Carbon Steel:**

(i) It is used for making tools such as drills, files, chisels.

(ii) Many machine parts are made with high carbon steel since it is capable of withstanding shocks and vibrations.

**(c) High Tensile Steel:** It contains 0.8% carbon and 0.6% manganese. The strength of this steel is quite high. High tensile steel wires are used in prestressed concrete works.

**Types of Steel Sections:**

- Rolled Steel I-sections (Beam sections).
- Rolled Steel Channel Sections.
- Rolled Steel Tee Sections.
- Rolled Steel Angles Sections.
- Rolled Steel Bars.
- Rolled Steel Tubes.
- Rolled Steel Flats.
- Rolled Steel Sheets

**Prefabrication Technologies:**

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site and transporting complete assembles to the construction site where the structure is to be located.

**Prefabrication materials**

- Structural insulated panels (SIPs).
- Insulating concrete forms (ICFS).
- Prefab foundation system.
- Steel framing.
- Concrete framing.
- Large - modular system

| Prefabrication Technology | Types |
|---|---|
| **Formwork Systems** | 1. Monolithic concrete construction system<br>2. Modular tunnel form<br>3. Kayson's formwork system:<br>4. Sismo building technology |
| **Precast Sandwich Panel Systems** | 1. Panel prefab system:<br>2. Advanced building system<br>3. Ferrocement sandwich panel<br>4. Structural insulated panels (SIPs)<br>5. Glass fibre reinforced gypsum (GFRG) panel system<br>6. Prefabricated modular units using organo-clay/ glass fibre reinforced polymer composite |
| **Light Gauge Steel Structural Systems** | 1. Pods- Small rooms of light steel frame with all fittings and finishing |
| **Precast Concrete Construction Systems** | 1. Industrialized 3-S System using cellular light weight concrete slabs & precast columns:<br>2. Pre-stressed precast system using hollow core slab, beams, columns etc:<br>3. Waffle crete building system: |
| **Steel Structural Systems** | 1. Speed floor system:<br>2. Timber-concrete prefabricated composite wall system:<br>3. Factory made fast track modular building system |

**Advantages:**

- The requirement for formwork, shuttering and scaffolding is significantly reduced as Self-supporting ready-made components are used.
- Construction time is reduced thus resulting in lower labour costs.
- Reduced amount of waste materials than in site built construction.
- Reduction in Construction time allowing an earlier return of the principal invested.
- Building ensures accurate conformity to building standards and superior quality assurance.

- High-energy efficiency along with quality control and factory sealing.
- Prefabrication site can be positioned where skilled labour is more readily accessible and the expenses of labour, power, materials, space and overheads are minimized.
- Prefabrication allows construction all over the year irrespective of the weather (related to excessive cold, heat, rain, snow, etc.).
- Construction material wastage is less.
- Independent of climatic condition.
- In off-site construction safety and comfort level of worker are higher.

**AGGREGATES:**

Aggregates are coarse particulate rock-like material consisting of a collection of particles ranging in size from < 0.1 mm to > 50 mm. It includes gravel, crushed rock, sand, recycled concrete, slag, and synthetic aggregate.

**FINE AGGREGATE & COARSE AGGREGATES:**

| Sl No | Scopes | Fine Aggregate (FA) | Coarse Aggregate (CA) |
|---|---|---|---|
| 1 | Definition | Fine aggregates are small-size filler materials in construction. | Coarse aggregates are larger-size filler materials in construction. |
| 2 | Size of Particles | Fine aggregates are the particles that pass through a 4.75 mm sieve and retain on a 0.075 mm sieve. | Coarse aggregates are the particles that retain on a 4.75 mm sieve. |
| 3 | Materials | Sand, surki, stone screenings, burnt clays, cinders, fly ash, etc are used as fine aggregate in concrete. | Brick chips (broken bricks), stone chips (broken stones), gravels, pebbles, clinkers, cinders, etc. are used as coarse aggregate in concrete. |
| 4 | Sources | River sand or machine sand, crushed stone sand, and crushed gravel sand are the major sources of fine aggregate. | Dolomite aggregates, crushed gravel or stone, and the natural disintegration of rock are the major sources of coarse aggregate. |
| 5 | Surface Area | The surface area of fine aggregates is higher. | The surface area of coarse aggregates is less than fine aggregates. |

| Sl No | Scopes | Fine Aggregate (FA) | Coarse Aggregate (CA) |
|---|---|---|---|
| 6 | Function in Concrete | The voids between the coarse aggregate are filled up by fine aggregate. | Coarse aggregate acts as inert filler material for concrete. |
| 7 | Uses | Fine aggregates are used in mortar, plaster, concrete, filling of road pavement layers, etc. | Coarse aggregates are mainly used in concrete, railway track ballast, etc. |

# UNIT-2
# SURVEYING

**Definition:**

Surveying is the art of making measurements of objects on, above or beneath the ground to show their relative positions on paper. The relative position required is either horizontal, or vertical, or both.

Or

Surveying is used to the measurement of objects in their horizontal positions.

- Measurements to determine their relative vertical positions is known as levelling.

**USES OF SURVEYING:**

(i) Plans prepared to record property lines of private, public and government lands help in avoiding unnecessary controversies.
(ii) Maps prepared for marking boundaries of countries, states, districts etc., avoid disputes.
(iii) Locality plans help in identifying location of houses and offices in the area.
(iv) Road maps help travellers and tourist.
(v) Topographic maps showing natural features like rivers, streams, hills, forests help in planning irrigation projects and flood control measures.
(vi) For planning and estimating project works like roads, bridges, railways, airports, water supply and waste water disposal surveying is required.
(vii) Marine and hydrographic survey helps in planning navigation routes and harbours.
(viii) Military survey is required for strategic planning.
(ix) Mine surveys are required for exploring mineral wealth.
(x) Geological surveys are necessary for determining different strata in the earth crust so that proper location is found for reservoirs.
(xi) Archaeological surveys are useful for unearthing relics of antiquity.
(xii) Astronomical survey helps in the study of movements of planets and for calculating local and standard times.

**OBJECTIVES OF SURVEYING:**

The main object of any survey is the preparation of a plan or a map showing all the features of the area under consideration. A plan may be defined as a projection of the ground and the features upon it on a horizontal plane. So, a plan is the representation to some scale of the area and the objects contained in it. The representation is called a map if the scale adopted is small, while it is called a plan if the scale is large. For example, a map of India, a plan of a building.

**PRINCIPLES OF SURVEYING:**

(i) Work from whole to part

(ii) Take extra care in fixing new control points.

**TYPES OF SURVEYING:**

| Plane Surveying | Geodetic Surveying |
|---|---|
| The surveying in which earth surface is assumed as a plane and the curvature of the earth is ignored is known as plane surveying. | The surveying in which curvature of the earth is taken into account for all measurements is known as geodetic surveying. |
| It extends only over small areas, the line connecting two points on the earth is considered as a straight line | It extends over large areas and so any line connecting two points on the earth's surface is considered as an arc. |
| The angle between any two lines is considered as plane angle. | The angle between any two such arcs is treated as a spherical angle. |
| Surveys covering an area up to 260 $km^2$ | Surveys covering an area more than 260 $km^2$ |

**CLASSIFICATION OF SURVEYING**

Surveying may be classified on the following basis:

(i) Nature of the survey field

(ii) Object of survey

(iii) Instruments used and

(iv) The methods employed.

**Classification Based on Nature of Survey Field**

On this basis survey may be classified as land survey, marine or hydraulic survey and astronomical survey.

**Land Survey:** It involves measurement of various objects on land. This type of survey may be further classified as given below:

(a) Topographic Survey: It is meant for plotting natural features like rivers, lakes, forests and hills as well as man-made features like roads, railways, towns, villages and canals.

(b) Cadestal Survey: It is for marking the boundaries of municipalities, villages, talukas, districts,

states etc. The survey made to mark properties of individuals also come under this category.

(c) City Survey: The survey made in connection with the construction of streets, water supply and sewage lines fall under this category.

**Marine or Hydrographic Survey**: Survey conducted to find depth of water at various points in bodies of water like sea, river and lakes fall under this category. Finding depth of water at specified points is known as sounding.

**Astronomical Survey**: Observations made to heavenly bodies like sun, stars etc., to locate absolute positions of points on the earth and for the purpose of calculating local time is known as astronomical survey.

**Classification Based on Object of Survey**

On the basis of object of survey the classification can be as engineering survey, military survey, mines survey, geological survey and archeological survey.

**(a) Engineering Survey:** The objective of this type of survey is to collect data for designing civil engineering projects like roads, railways, irrigation, water supply and sewage disposals. These surveys are further sub-divided into:

- Reconnaissance Survey for determining feasibility and estimation of the scheme.
- Preliminary Survey for collecting more information to estimate the cost of the project, and
- Location Survey to set the work on the ground.

**(b) Military Survey:** This survey is meant for working out plans of strategic importance.

**(c) Mines Survey:** This is used for exploring mineral wealth.

**(d) Geological Survey**: This survey is for finding different strata in the earth's crust.

**(e) Archeological Survey:** This survey is for unearthing relics of antiquity.

**Classification Based on Instruments Used**

Based on the instruments used, surveying may be classified as:

(i) Chain survey

(ii) Compass survey

(iii) Plane table survey

(iv) Theodolite survey

(v) Tacheometric survey

(vi) Modern survey using electronic distance meters and total station

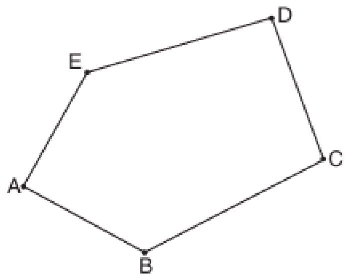
(vii) Photographic and Aerial survey

**Classification Based on Methods Employed**

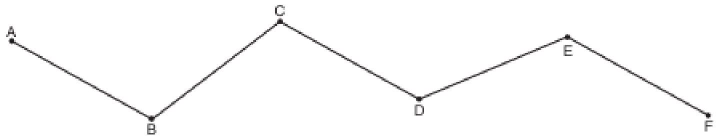
On this basis surveying is classified as triangulation and traversing.

**(i) Triangulation**: In this method control points are established through a network of triangles.

**(ii) Traversing:** In this scheme of establishing control points consists of a series of connected.




(a) Closed traverse




(b) Open traverse

**HORIZONTAL MEASUREMENTS**

Horizontal measurements in surveying refer to the measurements made on a horizontal plane, typically representing distances and angles along the Earth's surface. These measurements are crucial for mapping land, establishing boundaries, and creating accurate plans for construction or other purposes.

**Methods for Horizontal Measurements:**

**Distance Measurement:** Determining the length between two points on the ground. Traditionally, this was done using chains or tapes, but modern methods involve electronic distance measuring devices (EDM), total stations, or GPS.

**Angles and Bearings:** Measuring angles between lines or determining the direction of a line with respect to a reference direction (usually North). Instruments like theodolites, total stations, and compasses are used for angular measurements.

**Techniques Used:**

**Traversing:** A series of connected survey lines, where distances and angles between successive points are measured. It's used to determine the coordinates and distances between various points.

**Triangulation:** Determining distances indirectly by measuring angles in a series of connected triangles. This method is useful for large-scale surveys.

**Instruments for Horizontal Measurements:**

**Theodolite:** Measures horizontal and vertical angles precisely. It's often used for accurate angular measurements in surveying.

**Total Station:** Integrates EDM with a theodolite, allowing simultaneous measurement of distances and angles. It provides accurate and efficient horizontal and vertical measurements.

**GPS (Global Positioning System):** Utilizes satellites to provide precise horizontal positions on the Earth's surface. It's especially valuable for large-scale surveys and mapping.

## ANGULAR MEASUREMENTS:

Angular measurements in surveying involve the determination and measurement of angles between various lines or directions. These measurements are crucial for determining the layout, orientation, and relationships between different points on the Earth's surface. Angular measurements help create accurate maps, establish boundaries, and aid in construction and engineering projects.

### Instruments for Angular Measurements:

**Theodolite:** This instrument measures horizontal and vertical angles with high accuracy. It consists of a telescope mounted on a base that can rotate horizontally (for measuring azimuth or horizontal angles) and vertically (for measuring zenith or vertical angles).

**Total Station:** Integrates the functionality of a theodolite with an electronic distance measuring device (EDM), allowing simultaneous measurement of angles and distances. Total stations are commonly used in modern surveying due to their efficiency and accuracy.

### Types of Angular Measurements:

**Horizontal Angles:** These are measured in a horizontal plane and are usually referenced to a specific direction, such as the north direction. Bearings (i.e., angles measured clockwise from a north reference) or azimuths (angles measured clockwise from a reference meridian) fall under this category.

**Vertical Angles:** Measured in a vertical plane, vertical angles determine the elevation or depression of a line of sight concerning the horizontal plane. They are essential for establishing heights, slopes, and gradients in surveying.

### Methods of Angular Measurement:

**Direct Measurement:** Using instruments like theodolites or total stations to directly measure angles between survey lines or reference points.

Indirect Measurement: Utilizing trigonometry and geometric principles to calculate angles based on known measurements, especially when direct measurement is impractical or impossible.

**Accuracy and Error Correction:**

Surveyors must account for various sources of error in angular measurements, including instrumental errors, atmospheric conditions, improper centering of instruments, and human errors. Calibration of instruments, careful observation techniques, and applying appropriate corrections help ensure accurate angular measurements.

## BEARINGS:

Bearings in surveying refer to a method used to express direction or the angle between a reference direction (usually north) and a line. They are essential for describing the orientation of lines, boundaries, and other features on the Earth's surface.

**Types of Bearings:**

**True Bearing:** It is the angle measured clockwise from the true north (the North Pole) to a line or direction. True bearings are consistent and do not change based on location.

**Magnetic Bearing:** The angle measured clockwise from the magnetic north (the direction a compass needle points) to a line or direction. Magnetic bearings can vary due to the magnetic declination, which is the difference between true north and magnetic north at a specific location.

**Grid Bearing:** Refers to the angle measured clockwise from the grid north, which is the north direction of a map's grid system. Grid bearings are used in mapping and navigation on specific map projections.

**Representing Bearings:**

Bearings can be expressed in various formats:

**Whole Circle Bearing (WCB):** Ranges from 0° to 360°, where 0°/360° represents the north direction, 90° is east, 180° is south, and 270° is west.

**Quadrantal Bearing:** Divides the circle into four quadrants: NE, SE, SW, and NW, with angles ranging from 0° to 90° in each quadrant.

**Reduced Bearing:** Takes the form of an angle less than 90°, measured clockwise from the north or south direction.

**Applications of Bearings:**

**Surveying and Mapping:** Used to describe the direction of boundaries, property lines, and features on maps accurately.

**Navigation:** Helps in determining the direction to travel, especially in marine and aviation navigation.

**Civil Engineering:** Used in designing roads, railways, pipelines, and other infrastructure projects where accurate direction and alignment are crucial.

**Conversion between Bearings:**

Converting between true, magnetic, and grid bearings requires considering the local magnetic declination or any other relevant corrections to ensure accurate navigation and surveying.

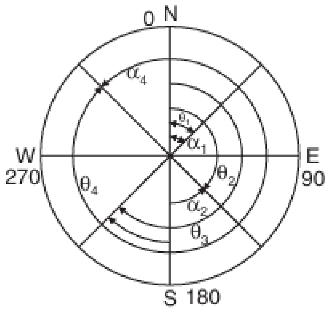
**WHOLE CIRCLE BEARING AND REDUCED BEARING:**

**In whole circle bearing (WCB)** the bearing of a line at any point is measured with respect to a meridian. Its value varies from zero to 360°, increasing in clockwise direction. Zero is north direction, 90° is east, 180° is south and 270° is west. This type of bearing is used in prismatic compass.

**In reduced bearing (RB) system,** bearings are measured from north or south direction towards east or west. Hence, angles are from 0 to 90°. This system of measuring bearings is used in Surveyor's compass and it is also known as Quadrantal Bearing (QB).

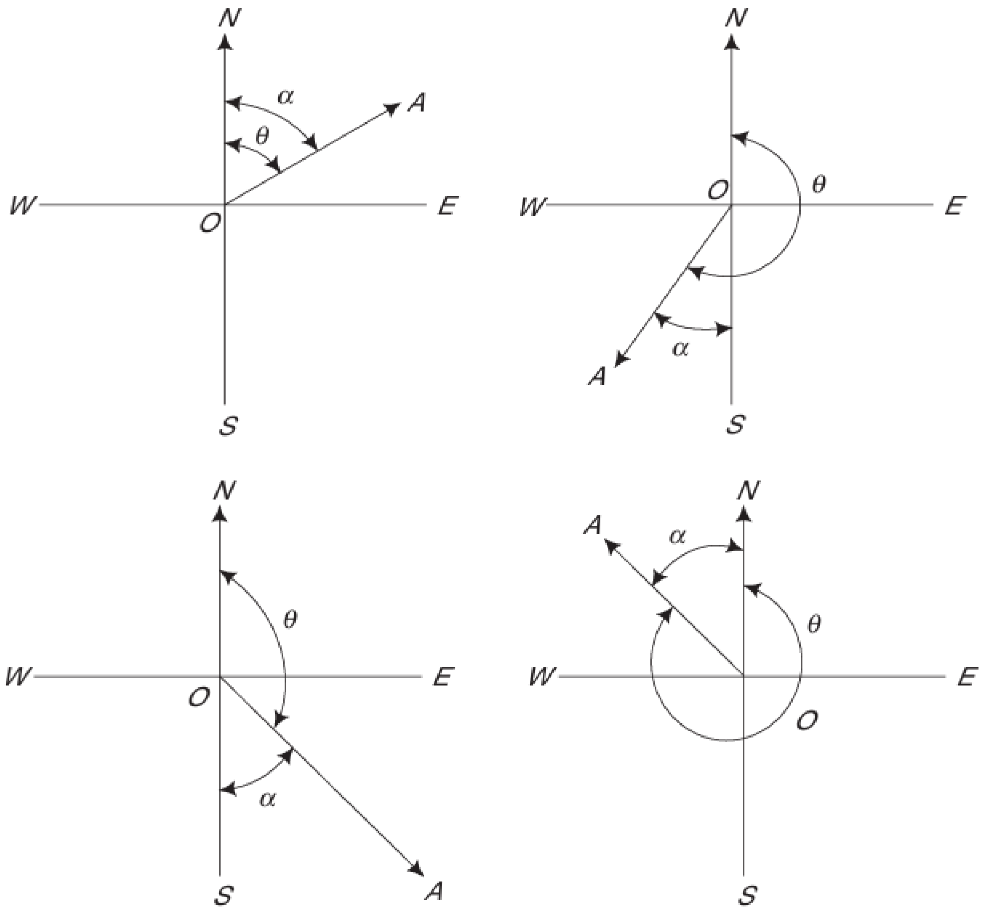
The bearing measured is designated with letter N or S in the beginning to indicate whether it is from north or south. The letter E or W written after the angle indicates whether the bearing read is towards east or west, respectively. The conversion of the bearing from one system to the other system can be easily carried out by drawing a sketch to indicate WCB or RB.

| *Quadrant in which bearing lies* | *Conversion relation* |
|---|---|
| NE | $\alpha = \theta$ |
| SE | $\alpha = 180° - \theta$ |
| SW | $\alpha = \theta - 180°$ |
| NW | $\alpha = 360° - \theta$ |




**CONVERSION OF WCB TO RB:**

| *Case* | *WCB between* | *Rule for RB* | *Quadrant* |
|---|---|---|---|
| I | 0° and 90° | WEB | NE |
| II | 90° and 180° | 180° – WCB | SE |
| III | 180° and 270° | WCB – 180° | SW |
| IV | 270° and 360° | 360° – WCB | NW |




When a line lies exactly along North, South, East or West, if

WCB of a line = 0°, then, RB is N

WCB of a line = 90°, then, RB is E 90°

WCB of a line = 180°, then, RB is S

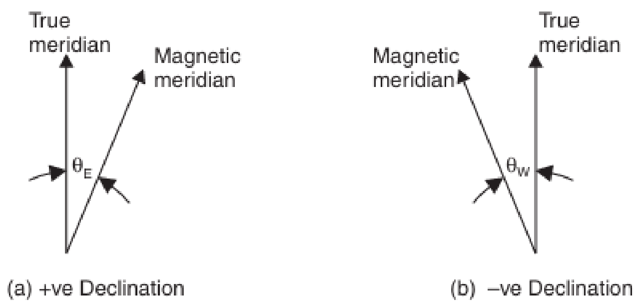
WCB of a line = 270°, then, RB is W 90°

**CONVERSION OF RB TO WCB:**

| *Case* | *RB Quadrant* | *Rule for WCB* | *WCB between* |
|---|---|---|---|
| I | NE | RB | 0° and 90° |
| II | SE | 180° – RB | 90° and 180° |
| III | SW | 180° + RB | 180° and 270° |
| IV | NW | 360° – RB | 270° and 360° |

**MAGNETIC DECLINATION:**

The magnetic meridian and the true meridian may not coincide with each other in a place. The horizontal angle between these two meridians is known as magnetic declination.




**LEVELLING:**

Levelling in surveying is a fundamental technique used to determine the height or elevation of points on the Earth's surface relative to a reference point, usually referred to as a datum. It's crucial in various engineering, construction, and mapping projects to ensure accurate measurements and proper alignment.

**Basic Components:**

**Level:** A Levelling instrument like a spirit level, theodolite, or an automatic level is used to measure height differentials between points.

**Levelling Staff/Rod:** A graduated rod placed at the point whose elevation is to be determined. It's marked with precise measurements in meters or feet.

**Types of Levelling:**

**Differential Levelling:** The most common method where the elevation differences between points are measured. It involves setting up the instrument at a known elevation (benchmark) and taking readings at various locations.

**Trigonometric Levelling:** Uses trigonometric formulas and angles observed through a theodolite to calculate elevations indirectly.

**Procedure for Differential Levelling:**

**Setup:** The level is placed at a known point with a known elevation (benchmark).

**Sighting and Reading:** The level is sighted on the Levelling staff held vertically at the point whose elevation is to be determined. The reading on the staff at the crosshair of the level is noted.

**Moving to New Points:** The level is then moved to different locations, and readings are taken again on the staff.

**Calculations:** The difference in readings between the benchmark and each new point gives the relative difference in elevations.

**Establishing Benchmarks:** Multiple benchmarks are used to create a network of known elevations across the survey area.

**Sources of Error and Corrections:**

**Instrumental Error:** Calibration issues or imperfections in the instrument.

**Natural Factors:** Atmospheric conditions, such as temperature and pressure, affecting the accuracy of readings.

**Human Error:** Incorrect readings or misalignment while sighting.

**Collimation Error:** The line of sight not being perfectly horizontal due to optical misalignment in the instrument.

**Applications:**

**Construction:** Setting foundations, grading, and aligning structures.

**Hydrographic Surveying:** Determining water levels for rivers, lakes, and oceans.

**Road and Railway Construction:** Ensuring proper gradients and alignments.

**Cartography:** Creating accurate maps by establishing elevations.

**CONTOUR MAPPING**

Contour mapping is a technique used in cartography to represent the three-dimensional surface of the Earth on a two-dimensional map. It utilizes contour lines, which are imaginary lines connecting points of equal elevation, to depict the topography of an area.

**Characteristics of contour mapping:**

1. **Contour Lines:**

   **Continuous Lines:** Contour lines are continuous, never ending or intersecting, and represent specific elevations above a reference point (usually sea level).

   **Closely Spaced Lines:** Areas with steep slopes have contour lines closely spaced, indicating rapid changes in elevation. Conversely, gentle slopes are represented by widely spaced lines.

2. **Elevation Representation:**

   **Elevation Intervals:** Each contour line represents a specific elevation difference from adjacent lines (e.g., 10 meters, 20 feet).

   **Index Contours:** Highlighted thicker lines with labeled elevations, providing a reference point for interpreting the map.

3. **Topographic Features:**

   **Depiction of Landforms:** Contour lines portray hills, valleys, ridges, and depressions on the map.

   **Steepness and Slopes:** Closer contour lines indicate steeper slopes, while widely spaced lines represent gentle slopes.

4. **Interpretation and Visualization:**

   **Visualizing the Terrain:** Contour maps enable users to visualize the land's surface and understand its characteristics without being physically present.

**Terrain Analysis**: Helps in planning routes, understanding drainage patterns, and identifying suitable areas for construction or land use.

**5. Accurate Representation:**

**Survey Data Integration:** Contour maps are derived from field surveys, aerial photography, LiDAR (Light Detection and Ranging) technology, or satellite data to ensure accuracy.

**Cartographic Conventions:** Follow standardized symbols, scales, and legends to ensure readability and comprehension.

**6. Application:**

**Engineering and Construction:** Vital for planning roads, infrastructure, and urban development to account for terrain variations.

**Environmental Studies:** Useful in studying watersheds, erosion, and land use planning.

**Recreation and Navigation:** Assist hikers, climbers, and outdoor enthusiasts in understanding the terrain for safe navigation.

**7. Limitations and Interpretation:**

**Omission of Vertical Features:** Some vertical features like cliffs or overhangs might not be accurately represented.

**Scale Dependency:** The scale of the map determines the level of detail and accuracy of the contours.

**Interpolation Errors:** Errors might occur during interpolation between surveyed points.

**PROBLEMS:**

1. **(a) Convert the following reduced bearings into whole circle bearings:**
   **(i) N 65° E (ii) S 43° 15′ E (iii) S 52° 30′ W (iv) N 32° 42′ W**

**Sol:** Let ‘θ’ be whole circle bearing.

(i) Since it is in NE quadrant,

$$\theta = \alpha = 65° \text{ Ans.}$$

(ii) Since it is in south east quadrant

$$43° \, 15' = 180° - \theta$$

or $$\theta = 180° - 43° \, 15' = 136° \, 45' \text{ Ans.}$$

(iii) Since it is in SW quadrant

$$52° \, 30' = \theta - 180°$$

or $$\theta = 180° + 52° \, 30' = 232° \, 30'$$

(iv) Since it is in NW quadrant,

$32° 42' = 360° – \theta$

or $\theta = 360° – 32° 42' = 327° 18'$

**2. (b) Convert the following whole circle bearings to reduced bearings:**

**(i) 148° (ii) 65° (iii) 285° (iv) 215°**

**Sol:** (i) $148^0$ is in the SE direction

AB= S(180-148)E= S$32^0$E

(ii) $65^0$ is in the NE direction

BC=N(90-65)E= N$25^0$E

(iii) $285^0$ is in the NW direction

CD= N(360-285)W= N$75^0$W

(iv) $215^0$ is in the SW direction

AD= S(215-180)W = S$35^0$W

**3. In a closed traverse the following bearings were observed with a compass. Calculate the interior angles.**

| *Line* | *Fore bearing* |
|---|---|
| *AB* | *65° 00′* |
| *BC* | *125° 30′* |
| *CD* | *200° 00′* |
| *DE* | *265° 15′* |
| *EA* | *330° 00′* |

**Sol:**

| *Line* | *Fore bearing* | *Back bearing* |
|---|---|---|
| AB | 65° 00′ | 245° 00′ |
| BC | 125° 30′ | 305° 30′ |
| CD | 200° 00′ | 20° 00′ |
| DE | 265° 15′ | 85° 15′ |
| EA | 330° 00′ | 150° 00′ |

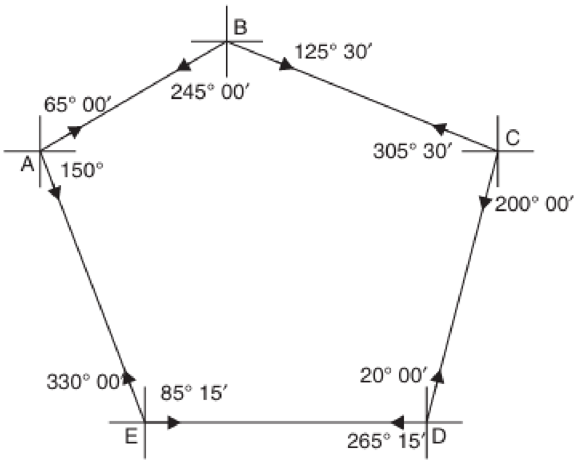



**Fig. 13.5**

Referring to figure:

$$\angle \mathbf{A} = 150°\ 00' - 65°\ 00' = \mathbf{85°\ 00'}$$

$$\angle \mathbf{B} = 245°\ 00' - 125°\ 30' = \mathbf{119°\ 30'}$$

$$\angle \mathbf{C} = 305°\ 30' - 200°\ 00' = \mathbf{105°\ 30'}$$

$$\angle \mathbf{D} = (360° - 265°\ 15') + 20°\ 00' = \mathbf{114°\ 45'}$$

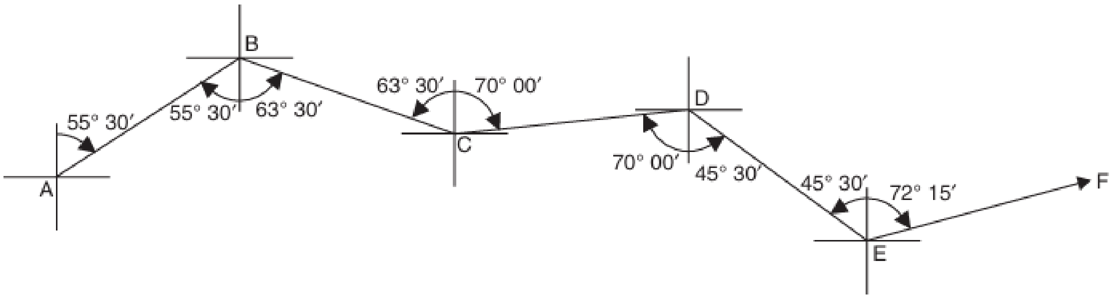
$$\angle \mathbf{E} = (360° - 330°\ 00') + 85°\ 15' = \mathbf{115°\ 15'}$$

**4. . The angles observed with a surveyor compass in traversing the lines AB, BC, CD, DE and EF are as given below. Compute the included angles and show them in a neat sketch.**

| *Line* | *Fore bearing* |
|---|---|
| *AB* | *N 55° 30′ E* |
| *BC* | *S 63° 30′ E* |
| *CD* | *N 70° 00′ E* |
| *DE* | *S 45° 30′ E* |
| *EF* | *N 72° 15′ E* |

**Sol:**

| *Line* | *FB* | *BB* |
|---|---|---|
| AB | N 55° 30′ E | S 55° 30′ W |
| BC | S 63° 30′ E | N 63° 30′ W |
| CD | N 70° 00′ E | S 70° 00′ W |
| DE | S 45° 30′ E | N 45° 30′ W |
| EF | N 72° 15′ E | S 72° 15′ W. |




$$\angle \mathbf{B} = 55° 30' + 63° 30' = \mathbf{119° 00'}$$

$$\angle \mathbf{C} = 63° 30' + 70° 00' = \mathbf{133° 30'}$$

$$\angle \mathbf{D} = 70° 00' + 45° 30' = \mathbf{115° 30'}$$

$$\angle \mathbf{E} = 45° 30' + 72° 15' = \mathbf{117° 45'}$$

**5. (a) A surveyor takes two readings on a levelling staff held at points A and B. The readings are 2.5 meters at point A and 3.8 meters at point B. If the instrument is placed at point A, what is the difference in height between points A and B?**

**Sol:** The difference in height between points A and B can be found by subtracting the reading at point A from the reading at point B.

Reading at point A = 2.5 meters

Reading at point B = 3.8 meters

Height difference = Reading at point B - Reading at point A

Height difference = 3.8 meters - 2.5 meters = 1.3 meters

Therefore, the difference in height between points A and B is 1.3 meters.

**5(b). A levelling survey is conducted between two points, A and B, with the following readings: 1.2 meters at point A and 4.5 meters at point B. If the distance between A and B is 50 meters, what is the gradient between the two points?**

**Sol:** The gradient can be calculated using the height difference and the horizontal distance between the points.

Height difference = Reading at point B - Reading at point A

Height difference = 4.5 meters - 1.2 meters = 3.3 meters

Gradient = Height difference / Horizontal distance Gradient

= 3.3 meters / 50 meters = 0.066

Therefore, the gradient between points A and B is 0.066 (or 6.6%).

**5(c): A levelling instrument is set up at a known elevation of 100 meters. Readings on a levelling staff at points A, B, and C are 2.5 meters, 4.8 meters, and 1.3 meters, respectively. Determine the elevation of points B and C.**

**Sol:** Given the instrument's known elevation at the setup point as 100 meters:

Reading at point A = 2.5 meters

Reading at point B = 4.8 meters

Reading at point C = 1.3 meters

Elevation at point B = Known elevation + Reading at point B

Elevation at point B = 100 meters + 4.8 meters = 104.8 meters

Elevation at point C = Known elevation + Reading at point C

Elevation at point C = 100 meters + 1.3 meters = 101.3 meters

Therefore, the elevations of points B and C are 104.8 meters and 101.3 meters

# UNIT-3

# TRANSPORTATION ENGINEERING

## INTRODUCTION:

Transportation engineering is a branch of civil engineering that deals with the planning, design, construction, and maintenance of transportation systems. Its primary focus is on creating efficient, safe, and sustainable systems for the movement of people and goods from one place to another.

**Overview of Transportation Engineering:**

**Modes of Transportation:** Transportation engineering encompasses various modes of transportation, including:

Roadways: Highways, streets, and local roads.

Railways: Train and subway systems.

Airways: Airports, air traffic control systems.

Waterways: Ports, canals, rivers, and marine transport.

Pipelines: Transport of liquids or gases.

**Planning and Design:** Engineers in this field are responsible for planning and designing transportation infrastructure. This involves considering factors like traffic flow, environmental impact, land use, safety, and cost-effectiveness.

**Traffic Engineering:** It involves analyzing traffic patterns, managing traffic flow, and optimizing the use of transportation infrastructure. This includes traffic signal timing, lane markings, signage, and intelligent transportation systems (ITS).

**Infrastructure Development:** Building and maintaining transportation infrastructure is a core aspect. This includes constructing roads, bridges, tunnels, railways, airports, and other related structures.

**Safety and Regulations:** Transportation engineers focus on ensuring safety standards and regulations are met within the transportation network. This involves measures such as road signage, speed limits, lighting, and safety barriers.

**Environmental Considerations:** There's a growing emphasis on creating environmentally friendly transportation systems. Engineers work on reducing emissions, implementing green transportation methods, and mitigating the environmental impact of transportation systems.

**Public Transportation:** Designing and optimizing public transportation systems, such as buses, subways, light rail, and other mass transit options to improve accessibility and reduce congestion.

**Research and Innovation:** Continuous research and development are crucial in transportation engineering. This includes exploring new materials, technologies, and methodologies to enhance transportation efficiency, safety, and sustainability.

**IMPORTANCE:**

**Economic Development:** Efficient transportation systems facilitate economic growth by connecting regions, enabling the movement of goods and services, and supporting trade and commerce.

**Quality of Life:** Well-planned transportation systems enhance accessibility, reduce travel time, and contribute to an improved quality of life for communities by providing better connectivity.

**Safety:** Ensuring safe transportation systems is paramount. Engineering solutions aim to reduce accidents, injuries, and fatalities on roads and other transport networks.

**Sustainability:** With the increasing concern for environmental impact, transportation engineers focus on creating sustainable systems that reduce carbon footprint and promote eco-friendly modes of transport.

**IMPORTANCE OF TRANSPORTATION IN NATIONS ECONOMIC DEVELOPMENT**

Transportation plays a pivotal role in the economic development of nations. Its importance lies in facilitating the movement of goods, people, and services, thereby impacting various aspects of the economy:

**Market Access and Trade Facilitation:**

1. **Connectivity:** Transportation networks, including roads, railways, ports, and airports, connect regions and facilitate access to markets, allowing businesses to reach customers, suppliers, and resources efficiently.
2. **Trade Expansion:** Efficient transportation systems enable the import and export of goods, promoting trade between regions and countries, which is crucial for economic growth and expanding markets.

**Economic Growth and Productivity:**

1. **Infrastructure Development:** Investments in transportation infrastructure create jobs and stimulate economic activity through construction, maintenance, and operation, contributing to GDP growth.
2. **Supply Chain Efficiency:** Efficient transportation systems reduce logistics costs, improve supply chain management, and enhance productivity, allowing businesses to operate more competitively.

**Regional Development and Accessibility:**

1. **Accessibility:** Improved transportation links enhance accessibility to remote or underserved areas, opening up opportunities for development and attracting investments.
2. **Urbanization and Connectivity:** Transportation networks support urbanization by connecting rural areas to cities, promoting access to education, healthcare, and employment opportunities.

**Investment and Innovation:**

1. **Technological Advancements:** Investments in transportation infrastructure drive innovation, fostering the development of new technologies and transportation modes, such as high-speed rail or electric vehicles.

2. **Attracting Investment:** Nations with efficient transportation systems often attract more foreign direct investment (FDI) due to better connectivity and logistical advantages.

**Employment and Social Development:**

1. **Job Creation:** The transportation sector itself creates employment opportunities, from drivers and logistics personnel to engineers and infrastructure developers.
2. **Social Mobility:** Improved transportation allows for greater social mobility, enabling people to access education, healthcare, and employment opportunities beyond their immediate vicinity.

**Environmental and Sustainability Impact:**

1. **Environmental Considerations:** Sustainable transportation systems, such as public transit, eco-friendly vehicles, and efficient logistics, reduce carbon emissions and contribute to environmental conservation.
2. **Green Economy:** Investments in sustainable transportation solutions support the transition towards a green economy, promoting cleaner and more efficient transportation modes.

**TYPES OF HIGHWAY PAVEMENTS:**

Highway pavements are crucial components of road infrastructure, providing a durable and smooth surface for vehicles to travel. Various types of highway pavements are designed and constructed based on factors like traffic volume, climate, soil conditions, and available materials. Here are some common types:

**Flexible Pavements:**

1. **Asphalt Concrete (AC) Pavement:** Also known as hot mix asphalt (HMA), it consists of asphalt binder and aggregate. AC pavements are flexible, durable, and offer smooth riding surfaces. They're commonly used for highways due to their ability to withstand heavy traffic loads.
2. **Bituminous Surface Treatments (BST):** These are thin layers of bituminous materials (such as asphalt emulsions or cutbacks) sprayed on existing pavements. BSTs provide waterproofing and skid resistance, extending the life of older pavements.

**Rigid Pavements:**

1. **Portland Cement Concrete (PCC) Pavement:** Constructed with a mixture of Portland cement, water, and aggregates, PCC pavements are rigid, durable, and resistant to heavy traffic loads. They have long service lives but are more costly to construct than flexible pavements.

**Composite Pavements:**

1. **Composite Pavements:** These combine the characteristics of both flexible and rigid pavements. They usually consist of a layer of asphalt concrete overlying a layer of Portland cement concrete. Composite pavements utilize the benefits of both materials, providing strength and durability.

**Other Specialized Pavements:**

1. **Permeable Pavements:** Designed to allow water to pass through the surface, reducing stormwater runoff and improving water quality. They're environmentally friendly and commonly used in areas where drainage is critical.
2. **Quiet Pavements:** These pavements aim to reduce noise pollution from traffic. They incorporate special materials or surface textures to absorb or diminish noise, improving the quality of life for nearby residents.

**Factors Influencing Pavement Choice:**

- **Traffic Load:** Pavement type is often selected based on the expected volume and weight of traffic.
- **Climate and Environment:** Weather conditions and temperature variations affect pavement performance. Different materials are used in various climates to withstand freeze-thaw cycles, heat, and rainfall.
- **Cost and Availability of Materials:** The availability and cost of materials influence pavement choice. Some regions might opt for specific pavements due to material availability and affordability.
- **Maintenance Requirements:** Pavements with different materials have varying maintenance needs. Factors like ease of repair and maintenance play a role in pavement selection.

**Flexible Pavements:**

1. **Composition:** Comprised of multiple layers: a flexible surface course (asphalt or bitumen), base course, and sub-base course.
2. **Material:** Uses bituminous materials like asphalt concrete as the surface layer, providing flexibility to the pavement structure.
3. **Flexibility:** Designed to distribute loads over a wider area, allowing it to flex under traffic loads. It "bends" or deforms slightly under heavy loads.
4. **Construction:** Typically constructed in multiple layers, starting with a sub-base layer, followed by a base course, and finished with the asphalt surface layer.
5. **Maintenance:** Generally requires more frequent maintenance due to the need for periodic resurfacing or resealing to maintain the integrity of the asphalt surface.
6. **Performance:** Suitable for roads with moderate to high traffic volumes and areas where the underlying soil may experience seasonal changes.

**Rigid Pavements:**

1. **Composition:** Consists of a single layer of Portland cement concrete (PCC) laid on a prepared sub-base or subgrade.
2. **Material:** Uses rigid and durable concrete, providing strength and rigidity to the pavement structure.
3. **Stiffness:** Exhibits high stiffness and does not deform significantly under heavy loads. It distributes loads more directly to the subgrade.

4. **Construction:** Usually constructed as a single thick layer of concrete directly over the prepared subgrade or base.
5. **Maintenance:** Generally requires less frequent maintenance compared to flexible pavements. However, repairs might be more complicated if damage occurs.
6. **Performance:** Ideal for roads with heavy traffic loads, such as highways and airports, where durability and resistance to deformation are essential.

**Key Differences:**

1. **Material:** Flexible pavements use bituminous materials like asphalt, while rigid pavements use concrete.
2. **Load Distribution:** Flexible pavements distribute loads over a wider area, flexing under heavy loads, whereas rigid pavements transmit loads more directly to the subgrade without significant deformation.
3. **Construction:** Flexible pavements are constructed in layers, while rigid pavements are typically a single layer of concrete.
4. **Flexibility:** Flexible pavements are more flexible and adapt to minor ground movement, while rigid pavements are stiff and less flexible.
5. **Maintenance:** Flexible pavements generally require more frequent maintenance, while rigid pavements might need less frequent but potentially more complex repairs if damage occurs.

**Harbor Engineering:**

1. **Purpose:** Harbor engineering deals with the design, construction, and maintenance of harbors, ports, and coastal structures used for docking, loading/unloading vessels, and protecting shorelines.
2. **Components:** It includes designing breakwaters, quays, jetties, docks, and other maritime structures to provide safe and efficient facilities for shipping and handling cargo.
3. **Challenges:** Engineers need to consider wave action, tidal forces, sedimentation, vessel traffic, and environmental impact when designing and maintaining harbour infrastructure.

**Tunnel Engineering:**

1. **Purpose:** Tunnel engineering involves the planning, design, and construction of tunnels for transportation, utilities, or other purposes, providing passages through mountains, beneath water bodies, or urban areas.
2. **Types of Tunnels:** Tunnels can be categorized as road tunnels, rail tunnels, water supply tunnels, or utility tunnels, each with its own specific design considerations.
3. **Construction:** Engineers employ various methods like cut-and-cover, drilling and blasting, tunnel boring machines (TBMs), and NATM (New Austrian Tunneling Method) to excavate and construct tunnels.

4. **Safety:** Ensuring structural integrity, proper ventilation, emergency exits, and adequate lighting are critical for tunnel safety.

**Airport Engineering:**

1. **Purpose:** Airport engineering involves the planning, design, construction, and operation of airports, including runways, taxiways, terminals, and support facilities to facilitate air travel.
2. **Components:** Engineers focus on runway orientation, length, and surface strength, terminal building design, air traffic control systems, and safety measures.
3. **Regulations:** Compliance with aviation regulations, security measures, noise control, and environmental impact assessments are crucial aspects in airport engineering.
4. **Technological Advancements:** Continuous advancements in technology, such as navigational aids, runway lighting, and airport management systems, contribute to the efficiency and safety of airports.

**Railway Engineering:**

1. **Purpose:** Railway engineering involves the planning, design, construction, and maintenance of railway systems, including tracks, stations, signaling, and rolling stock.
2. **Track Design:** Engineers focus on track alignment, curvature, gradients, and materials to ensure safe and efficient train operations.
3. **Safety Measures:** Implementation of signaling systems, level crossings, track maintenance, and measures to prevent accidents are vital in railway engineering.
4. **High-Speed Rail:** Advancements in railway technology have led to the development of high-speed rail systems, demanding specialized engineering for safety, speed, and comfort.

## WATER RESOURCES AND ENVIRONMENTAL ENGINEERING

Water resources and environmental engineering are interconnected fields that focus on the management, conservation, and protection of water-related systems and the environment. Here's an introduction to these disciplines:

**WATER RESOURCES ENGINEERING:**

1. **Purpose:** Water resources engineering deals with the planning, development, and management of water resources such as rivers, lakes, groundwater, and reservoirs for various purposes like drinking water supply, irrigation, hydropower generation, and flood control.
2. **Key Components:**
    - **Water Supply:** Involves the design and construction of systems for collecting, treating, and distributing clean water for domestic, industrial, and agricultural use.
    - **Hydrology:** Studies the occurrence, distribution, movement, and properties of water in the atmosphere, on the earth's surface, and underground.
    - **Hydraulics:** Focuses on the behavior of fluids and their interaction with structures, including the design of channels, pipelines, and flood control systems.
    - **Water Quality Management:** Addresses water pollution, treatment processes, and methods to maintain or improve water quality.
3. **Challenges:** Water resources engineers face challenges related to climate change, increasing demand for water, pollution, water scarcity, and sustainable management of water resources.

**ENVIRONMENTAL ENGINEERING:**

1. **Purpose:** Environmental engineering aims to protect and improve the quality of the environment by addressing pollution control, waste management, and sustainability.
2. **Key Components:**
    - **Air Quality Management:** Involves monitoring and controlling air pollutants to ensure breathable and healthy air quality.
    - **Wastewater Treatment:** Focuses on the design and implementation of systems to treat and manage sewage and industrial effluents before discharge into water bodies.
    - **Solid Waste Management:** Deals with the collection, disposal, and recycling of solid waste to minimize environmental impact.
    - **Environmental Impact Assessment (EIA):** Evaluates the potential effects of projects on the environment before they are implemented.
3. **Challenges:** Environmental engineers work on challenges related to climate change, land degradation, pollution, waste management, and the conservation of natural resources.

**Intersection and Collaboration:**

1. **Interdisciplinary Approach:** Both fields often intersect, with water resources engineering contributing to environmental protection through sustainable water management, and environmental engineering ensuring that water systems and ecosystems are not adversely affected by human activities.
2. **Sustainability:** Both disciplines focus on sustainable practices and strategies to ensure the long-term health and preservation of natural resources and ecosystems.

**SOURCES OF WATER:**

1. **Surface Water Sources:**
    - **Rivers, Lakes, and Reservoirs:** Natural bodies of water that collect surface runoff and precipitation.
    - **Ponds:** Smaller bodies of water often created artificially for various purposes like irrigation or recreational use.
    - **Streams and Creeks:** Flowing bodies of water sourced from rainfall or melting snow.
2. **Groundwater Sources:**
    - **Wells:** Drilled into the ground to access groundwater reservoirs.
    - **Springs:** Natural points where groundwater emerges at the surface.

**Factors Influencing Water Quality:**

1. **Physical Characteristics:**
    - **Temperature:** Affects the solubility of gases and influences aquatic ecosystems.
    - **Turbidity:** Measures water clarity caused by suspended particles and affects light penetration.
    - **Colour:** It is caused due to the dissolved impurities such as fine clay and bacteria.
2. **Chemical Composition:**
    - **pH Level:** Measures acidity or alkalinity of water. Acceptable pH levels typically range between 6.5 and 8.5.
    - **Dissolved Oxygen:** Essential for aquatic life; levels should be above a certain threshold to support healthy ecosystems.
    - **Chemical Contaminants:** Includes heavy metals, pesticides, nitrates, phosphates, and other pollutants.
    - **Hardness:** it prevents water for the formation of lather with soap. It is caused due to mainly multivalent metallic cations.
    - **Alkalinity:** it can be identified by pH level. Range in between 8.5- 14 indicates the alkalinity of water, it is caused due mineral salts present in the water.
3. **Biological Characteristics:**
    - **Bacteria and Pathogens:** Presence of coliform bacteria, E. coli, and other pathogens can indicate contamination and pose health risks.

**Water Quality Specifications:**

1. **Drinking Water Standards:** Set by regulatory bodies like the World Health Organization (WHO) or Environmental Protection Agency (EPA) and include:

- Maximum allowable concentrations of contaminants such as heavy metals, pesticides, and microorganisms.
- Guidelines for pH, turbidity, dissolved oxygen, and other parameters.

2. **Water Treatment Requirements:**
    - Specifications for water treatment processes, such as filtration, chlorination, or reverse osmosis, to ensure the removal of contaminants to meet drinking water standards.
3. **Environmental Standards:**
    - Water quality specifications to protect aquatic ecosystems, including criteria for nutrient levels, dissolved oxygen, and other factors affecting biodiversity and ecosystem health.
4. **Industrial and Agricultural Standards:**
    - Standards and guidelines specific to industries or agriculture to prevent water pollution, manage runoff, and regulate the discharge of contaminants into water bodies.

## QUALITY OF WATER

**Impurities in water:-**

The impurities present in water may be divided in to the following three categories.

1. Physical impurities
2. Chemical impurities
3. Bacteriological impurities

**1) Physical impurities:-**

**a) Colour:-**The water bodies may be receiving colour from natural and artificial sources.

For public water supply the number on cobalt scale should not exceed 20 and should be preferably less than 10.

**b) Taste and odour:-**The eater possesses taste and odours due to various causes and they make the water unpleasant for drinking. The test is carried out by in having through tests of an Osmo scope. The taste and odour of water may also be tasted by thresholds number. For public water supply the threshold number should not be more that.

**c)Temperature: -** If the temperature of trade wastes which are discharged in to rivers or streams is high, their bodies. The desirable temperature of potable water is 10°c while temperature of 25°c is considered to be objectionable.

**d)Turbidity:-** The colloidal matter present in water interferes with passage of light and thus imparts turbidity to the water. The turbidity is expressed in terms of parts of suspended matter per million parts of water or shortly written as P.P.M. The permissible turbidity for drinking water is 5 to 10 p.p.m.

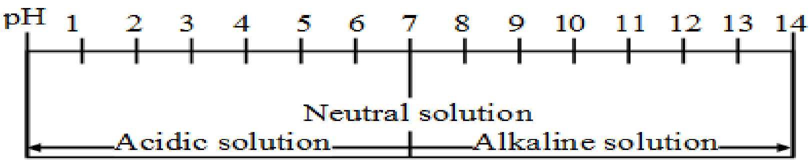
**2) Chemical impurities and chemical tests: -**

**1) Chlorides:-**The chloride contains especially of sodium chloride or salt, are workout for a sample of water. For portable water, the highest desirable level of chloride content is 25mg/ltr. And its maximum permissible limit is 600mg/ltr.

**2) Dissolved gasses: -**The water contains various gasses from its contact with the atmosphere and ground surfaces. The quantity of oxygen observed can then be calculated. This amount for portable water should be about 5 to 10 p.p.m.

**3) Hardness:-**The term hardness is defined as the ability of the water to cause precipitation of insoluble calcium and magnesium salts. For portable water, the hardness should preferably be more than 5 degrees and less than 8 degrees.

4) Hydrogen-ion concentration (pH value):- The acidity or alkalinity of water is measured in terms of its pH value or H-ion concentration.




**5) Alkalinity:-**The term alkalinity with reference to the water and waste water is defined as the capacity of substance contained in the water to take up hydronium ($H_3O^+$) to reach a defined pH value 4.3 to 14. The water having alkalinity less than 250 mg/ltr. Is desirable for domestic consumption and for R.C.C construction.

**6) Acidity:-**The term acidity with reference to the water and waste water is defined as the capacity of substance contained in water to take up Hydroxyl ions ($OH-$) to reach a defined pH value ( 0 to 8.2). The water having acidity more than 50mg/ ltr. Cannot be used for R.C.C construction.

**7) Metal and other chemical substances: -**

| Name of metal | Maximum permissible concentration in mg/ ltr |
|---|---|
| Arsenic ($A_s$) | 0.05 |
| Copper (Cu) | 1.00 |
| Fluoride(F) | 1.70 |
| Iron (Fe) | 0.30 |
| Zinc(Zn) | 5.00 |

**BACTERIOLOGICAL TESTS: -**

The examination of water for the presence of bacteria is very important. The bacteria are very small organism and it is not possible to detect them by microscope. The two standard bacteriological tests for the bacteriological examination of water:

(1) Total count or agar plate count test.

(2) B-coli test

**(1) Total count or agar plate count test:** For potable water, the total count should not exceed 100 per c.c.

**(2) B-coil test:**

Preparation:

- Ensure the engine is off and cool.
- Disconnect the spark plug wire from the spark plug.

Using a Spark Tester:

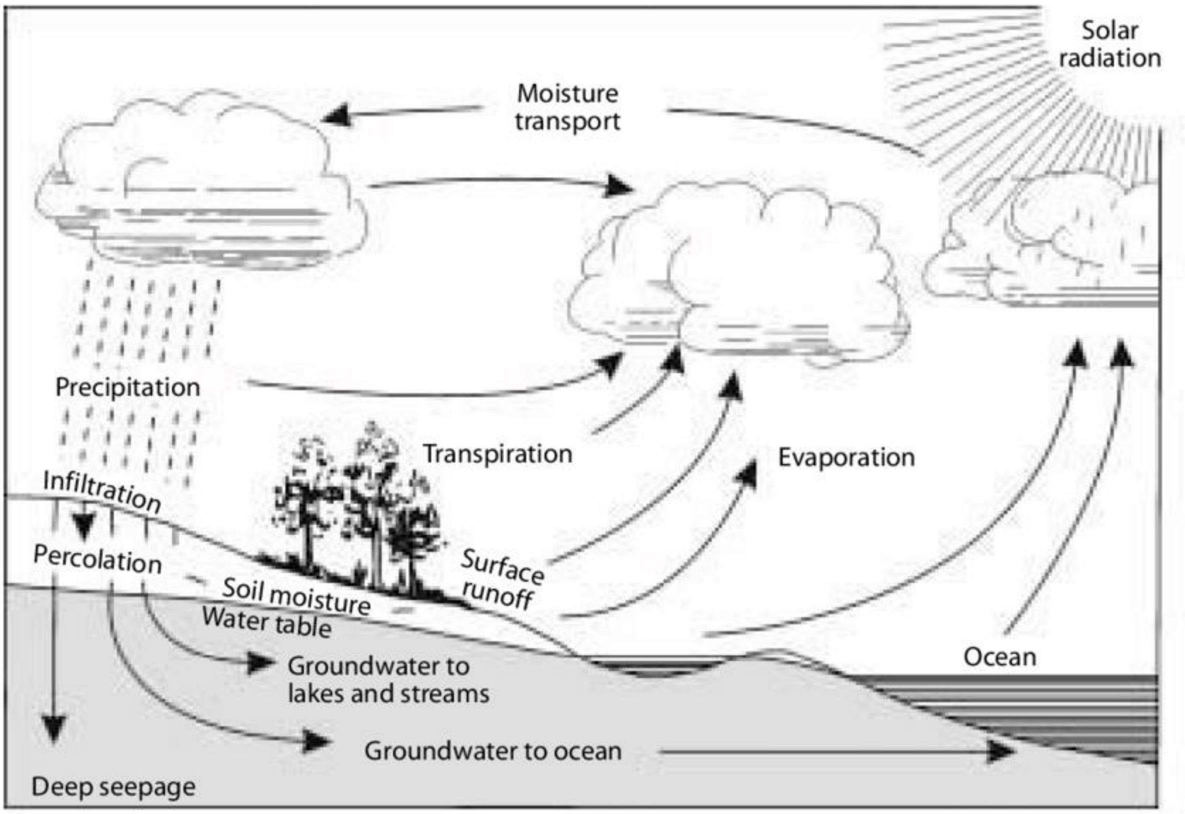
- Attach a spark tester to the spark plug wire and ground it to a clean metal part of the engine.
- Attempt to start the engine and observe the spark tester. If you see a spark, the coil is likely functioning correctly.

Using an Ohmmeter:

- Set your ohmmeter to the 20 K ohm range.
- Connect the negative probe to a metal part of the engine and the positive probe to the spark plug wire.
- Measure the resistance. A good coil should show a resistance between 2,500 and 5,000 ohms.

**HYDROLOGY:**

Hydrology is the study of water—its occurrence, distribution, movement, and properties on the Earth's surface, in the soil, and underground. It's a multidisciplinary field that encompasses various aspects related to the Earth's water cycle. Here's an introduction to hydrology:




**Key Components of Hydrology:**

1. **Water Cycle:** Hydrology examines the processes involved in the water cycle, which includes evaporation, condensation, precipitation, infiltration, runoff, and groundwater flow.
2. **Hydrologic Processes:**
   - **Precipitation:** Measurement and analysis of rainfall, snowfall, and other forms of precipitation.
   - **Evaporation and Transpiration:** Assessment of water loss from surfaces and vegetation.
   - **Runoff:** Study of surface water flow and its movement over land into streams, rivers, and other water bodies.
   - **Infiltration:** Investigation of water movement from the surface into the soil.
3. **Hydrologic Systems:**
   - **Surface Water:** Study of rivers, lakes, streams, and reservoirs and their behaviour in response to various factors.
   - **Groundwater:** Examination of water stored underground in aquifers and its movement through permeable rock or soil.

**Importance and Applications of Hydrology:**

1. **Water Resource Management:** Hydrology plays a vital role in managing water resources for various purposes, including drinking water supply, irrigation, hydropower generation, and ecosystem support.

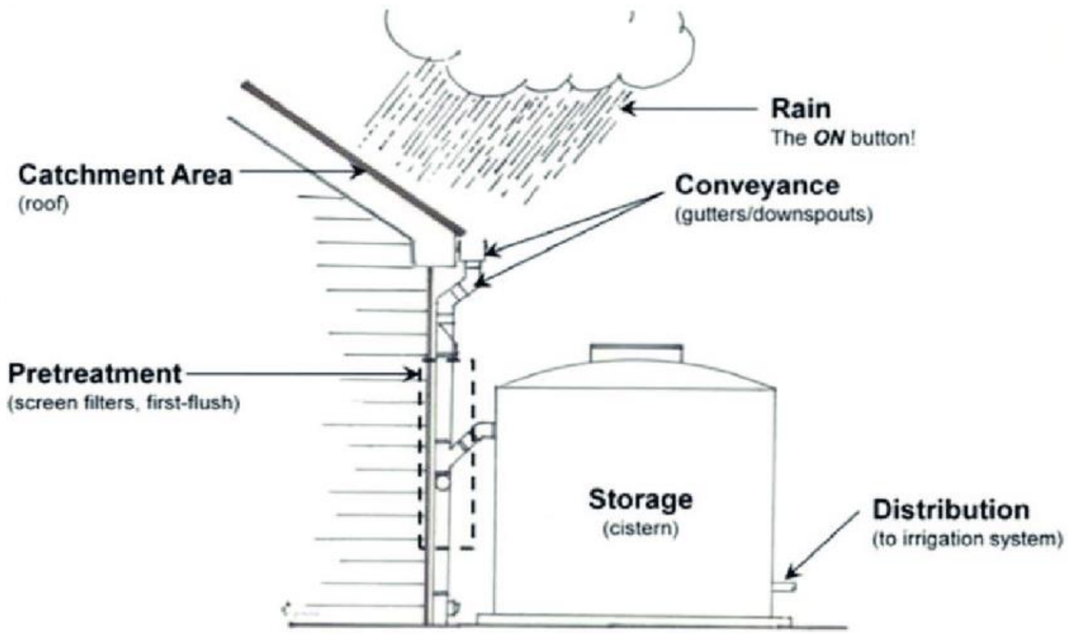
2. **Flood Prediction and Control:** By analysing rainfall patterns, river flow, and runoff, hydrologists contribute to forecasting and mitigating floods through early warning systems and infrastructure planning.
3. **Drought Monitoring:** Hydrology helps in understanding drought conditions by studying precipitation trends, groundwater levels, and soil moisture.
4. **Ecosystem Health:** By assessing water availability and quality, hydrology contributes to the preservation and management of ecosystems and biodiversity.
5. **Urban Planning:** Hydrological studies aid in urban drainage design, stormwater management, and infrastructure planning to prevent flooding and ensure water supply in cities.

**Techniques and Tools in Hydrology:**

1. **Hydrologic Modelling:** Use of mathematical models and computer simulations to predict and analyse water-related processes and behaviour.
2. **Remote Sensing:** Utilization of satellite imagery and remote sensing technologies to monitor changes in land cover, precipitation, and surface water.
3. **Field Measurements:** Collection of data through instruments like rain gauges, stream gauges, piezometers, and soil moisture sensors.
4. **GIS (Geographic Information Systems):** Integration of spatial data to analyze and visualize hydrologic information such as rainfall distribution, watershed delineation, and flood mapping.

**RAINWATER HARVESTING:**

Rainwater harvesting is a method of collecting and storing rainwater that falls on roofs, lands, or other surfaces for later use. It's an ancient practice that's gaining renewed attention due to water scarcity issues and the need for sustainable water management. Here's an overview of rainwater harvesting:



**Components of Rainwater Harvesting:**

1. **Catchment Area:** Surfaces like rooftops, terraces, or paved areas where rainwater falls and is collected.
2. **Conveyance System:** Gutters, downspouts, or channels that direct rainwater from the catchment area to storage tanks or reservoirs.
3. **Storage Tanks/Reservoirs:** Containers or underground tanks used to store collected rainwater for future use.
4. **Filtration and Treatment:** Systems like filters, screens, or treatment methods to remove debris, contaminants, or improve water quality before storage or use.

**Methods of Rainwater Harvesting:**

1. **Surface Runoff Harvesting:** Collecting rainwater from surfaces like rooftops and channelling it into storage containers.
2. **Infiltration Pit/Well Method:** Allowing rainwater to percolate into the ground through pits or wells, replenishing groundwater reserves.
3. **Roof Water Harvesting:** Capturing rainwater from roofs and transferring it directly to storage tanks or reservoirs.
4. **Check Dams and Contour Trenches:** Constructing barriers or trenches to slow down rainwater runoff, allowing it to infiltrate the soil and recharge groundwater.

**Benefits of Rainwater Harvesting:**

1. **Water Conservation:** Utilizing rainwater reduces reliance on freshwater sources, contributing to water conservation and reducing demand on municipal water supplies.
2. **Cost-Effective:** It's a cost-efficient method of augmenting water supply, especially in areas with limited access to clean water sources.
3. **Sustainable Practice:** Encourages sustainable water management by utilizing a natural resource and reducing reliance on energy-intensive water supply systems.
4. **Reduced Flooding and Erosion:** By capturing and storing rainwater, the risk of surface runoff causing erosion and flooding is minimized.

**Applications of Harvested Rainwater:**

1. **Domestic Use:** Non-potable uses like flushing toilets, laundry, gardening, and other outdoor activities.
2. **Irrigation:** Watering gardens, lawns, and agricultural fields during dry periods.
3. **Groundwater Recharge:** Allowing rainwater to infiltrate the ground, replenishing aquifers and maintaining groundwater levels.
4. **Emergency Water Supply:** Serving as a backup water source during emergencies or when municipal supplies are disrupted.

## WATER STORAGE AND CONVEYANCE STRUCTURES:

Water storage and conveyance structures are essential components of water management systems, facilitating the collection, storage, and movement of water for various purposes. Here's an overview of these structures:

**Water Storage Structures:**

1. **Reservoirs and Dams:**
    - **Purpose:** Large-scale storage facilities created by constructing dams across rivers or valleys to impound water for multiple uses like drinking water supply, irrigation, hydropower generation, and flood control.
    - **Types:** Gravity dams, arch dams, embankment dams, and concrete or rockfill dams, each designed based on site characteristics and purpose.
2. **Tanks and Cisterns:**
    - **Purpose:** Small to medium-sized storage containers typically used in urban or rural settings for household water storage, rainwater harvesting, or small-scale irrigation.
    - **Materials:** Made from various materials like concrete, plastic, or metal, based on durability, cost, and intended use.
3. **Aquifer Storage and Recovery (ASR):**
    - **Purpose:** Storing surplus water underground in natural aquifers during wet seasons for future extraction during dry periods.
    - **Process:** Injecting treated water into aquifers for storage and later recovery through wells.

**Water Conveyance Structures:**

1. **Canals:**
    - **Purpose:** Artificial channels designed for transporting water over long distances, supplying irrigation water to agricultural fields, or providing drinking water to communities.
    - **Types:** Main canals, branch canals, and distributary canals, each serving specific purposes in water distribution.
2. **Pipelines:**
    - **Purpose:** Underground or above-ground conduits used for transporting water over shorter distances, often used for municipal water supply, industrial purposes, or conveying treated wastewater.
    - **Materials:** Constructed using materials like steel, concrete, or plastic, based on factors like pressure, durability, and cost.

3. **Aqueducts:**
    - **Purpose:** Elevated or ground-level structures designed to transport water across valleys, ravines, or other obstacles without a significant change in elevation.
    - **Design:** Built with arches, bridges, or pipelines, depending on the terrain and distance to be covered.
4. **Pumping Stations:**
    - **Purpose:** Facilities equipped with pumps to lift water from lower elevations to higher elevations, overcoming natural gradients in conveyance systems.
    - **Applications:** Used in water distribution networks, wastewater treatment, and irrigation systems.

**Considerations in Design and Construction:**

1. **Hydraulic Efficiency:** Structures are designed to minimize water losses due to evaporation, seepage, or leaks during conveyance or storage.
2. **Structural Integrity:** Robust design and construction techniques ensure the stability and longevity of storage reservoirs, dams, and conveyance systems.
3. **Environmental Impact:** Careful planning considers the environmental impact of structures, such as maintaining aquatic ecosystems, preserving habitats, and minimizing disruption to natural landscapes.

**DAMS:**

1. **Purpose:** Dams are structures built across rivers or streams to impound water, creating reservoirs and altering natural water flow for various purposes.
2. **Types of Dams:**
    - **Gravity Dams:** Made from concrete or stone and rely on their weight to resist the force of water.
    - **Arch Dams:** Curved structures that transfer water pressure to abutments on the sides.
    - **Embankment Dams:** Built using compacted earth, rock, or other materials and often reinforced with concrete.
3. **Functions:**
    - **Water Storage:** Primary function is to store water for irrigation, municipal supply, industrial use, and hydroelectric power generation.
    - **Flood Control:** Help regulate water flow during heavy rainfall or melting snow to prevent flooding downstream.
    - **Hydropower Generation:** Provide a source of renewable energy by controlling the flow of water to turbines.

**RESERVOIRS:**

1. **Purpose:** Reservoirs are artificial lakes formed behind dams, holding large volumes of water collected from rivers or streams.
2. **Functions:**
   - **Water Storage:** Store water for use during dry periods, supplying drinking water, irrigation, and other human needs.
   - **Recreation:** Provide opportunities for boating, fishing, swimming, and other recreational activities.
   - **Ecological Support:** Create habitats for wildlife, support biodiversity, and regulate water temperature and flow for aquatic life.
3. **Management:**
   - **Water Release:** Controlled release of water from reservoirs for downstream needs, maintaining river flow and ecological balance.
   - **Sedimentation:** Accumulation of sediments in reservoirs over time, affecting storage capacity and requiring periodic dredging or management.

**Environmental Impact:**

1. **Positive Aspects:**
   - Dams and reservoirs can provide flood protection, water supply for communities and agriculture, renewable energy, and recreational opportunities.
2. **Challenges:**
   - Alteration of natural ecosystems, disruption of river habitats, changes in sediment flow, and impacts on fish migration patterns can pose ecological challenges.

# LECTURE NOTES
## ON

# BASICS OF MECHANICAL ENGINEERING
## (23AES0101)

## I B. Tech I/II Semester (AK23)
Department of Mechanical Engineering

**ANNAMACHARYA INSTITUTE OF TECHNOLOGY & SCIENCES**
**(Autonomous)**
Approved by AICTE, New Delhi & Permanent Affiliation to JNTUA, Anantapuramu
Two B.Tech Programmes (CSE & ECE) are accredited by NBA, New Delhi
Accredited by NAAC with 'A' Grade, Bangalore.
Recognized under sections 2(f) & 12(B) of UGC Act 1956

# UNIT – I

Engineering is the application of scientific knowledge and creative thought to solve real-time problems. Engineers design, plan, and create things starting from buildings and bridges to technology like smart phones and automobiles. They utilize their knowledge and skills to turn the ideas into practical feasible solutions that benefit the society. So, engineering is all about making things work better and finding solutions to day-to-day challenges.

Mechanical engineering is a broad and versatile field of engineering that plays a vital role in various other branches of engineering. Its principles and expertise intersect with and support many other engineering disciplines. Mechanical engineers often work besides civil engineers in the design and analysis of infrastructure projects like bridges, dams, and buildings. In mechatronics and robotics, mechanical and electrical engineers collaborate to develop complex systems involving both mechanical components and electrical controls. Power generation and distribution systems often require mechanical components and machinery designed by mechanical engineers.

Mechanical engineering forms the foundation of aerospace engineering, as it involves the design and analysis of aircraft systems. Mechanical engineers work on the structural integrity, propulsion, and control systems of aerospace vehicles. Mechanical engineers play a major role in the automotive industry.

Mechanical engineers contribute to environmental engineering by designing and developing systems for pollution control, waste management, and sustainable energy generation. They may work on technologies like wind turbines, solar panels, and water treatment plants.

Mechanical engineers are involved in the development of medical devices, such as prosthetic limbs, artificial organs, and medical imaging equipment. They apply their knowledge of mechanics to understand the biomechanics of the human body.

Mechanical engineers are crucial in the energy sector, working on the design and maintenance of power generation systems, including thermal, nuclear, and renewable energy technologies. They contribute to the development of energy-efficient systems and sustainable energy solutions. Mechanical engineers may work with computer engineers to develop simulations, modeling software, and control systems for mechanical and mechatronic applications.

## Role of Mechanical Engineering in Industries and Society:

Mechanical engineering plays a vital role in both industries and society. The following are some important functions of a mechanical engineer.

1. **Design and Innovation:** Mechanical engineers design a wide range of products and systems, from consumer goods like smart phones and cars to complex industrial machinery. Their unique designs lead to technological development and improve the quality of life.
2. **Manufacturing and Production:** They optimize manufacturing processes to ensure efficient and cost-effective production. This includes selecting the right materials, designing production methods, and ensuring quality control.
3. **Energy and Sustainability:** Mechanical engineers work on energy-efficient technologies, renewable energy systems helping industries reduce their carbon emissions and society shift towards cleaner energy sources.
4. **Transportation:** They contribute to the design of vehicles, aircraft, and public transportation systems, making travel safer, more comfortable, andefficient.
5. **Infrastructure:** Mechanical engineers play a crucial role in designing and maintaining infrastructure such as bridges, roads, and buildings, ensuring they are structurally sound and meet safety standards.
6. **Environmental Conservation:** They develop solutions for managing and minimizing environmental impacts, such as waste management systems and pollution control technologies.
7. **Safety:** Mechanical engineers focus on designing products and systems with safety in mind, preventing accidents and ensuring the well-being of individuals in both industrial and societal settings.
8. **Healthcare:** They contribute to the development of medical devices and equipment, from diagnostic tools to prosthetics, improving healthcare and saving lives.

9. **Research and Development:** Mechanical engineers engage in research to advance technology and develop innovative solutions for emerging challenges in various fields.

10. **Economic Growth:** Mechanical engineering drives economic development by promoting innovation, improving productivity, and creating job opportunities in various industries.

## Technologies in different Sectors such as Energy, Manufacturing, Automotive, Aerospace, and Marine:

**Energy Sector:** The energy sector has seen significant technological advancements in recent years aimed at improving efficiency, reducing environmental impact, and diversifying energy sources. Here are some key technologies in the energy sector:

a. **Renewable Energy Technologies:**

➢ **Solar Power**: Solar photo voltaic (PV) panels capture sunlight and convert it into electricity using photovoltaic cells. Solar power is clean, abundant, and increasingly cost-effective, making it a critical technology for reducing green house gas emissions.

➢ **Wind Power**: Wind turbines harness the kinetic energy of wind to generate electricity. Wind power is scalable and environmentally friendly energy source, particularly effective in windy regions.

➢ **Hydro power:** Hydro electric power plants use the energy of flowing water to generate electricity. They can provide a stable and consistent source of renewable energy, with minimal green house gas emissions.

➢ **Geothermal Energy**: Geothermal power plants tap into the Earth's heat to generate electricity. This technology offers continuous, base load power generation with minimal environmental impact.

➢ **Biomass Energy**: Biomass facilities convert organic materials like wood, crop residues, and agricultural waste into biofuels or electricity. Biomass can serve as a renewable alternative to fossil fuels.

b. **Energy Storage technologies:**

➢ **Battery Technology**: Advances in battery technology, including lithium- ion batteries, enable the efficient storage of energy from renewable sources. Energy storage helps balance supply and demand and provides back up power during outages.

➢ **Pumped Hydro Storage**: This technology stores energy by pumping water uphill during periods of low demand and releasing it downhill to generate electricity during peak demand, acting as a large-scale battery.

c. **Smart Grids and Grid Modernization:**

➢ **Smart Meters**: Advanced metering infrastructure (AMI) allows real-time monitoring of energy consumption, promoting energy efficiency and enabling demand-response programs.

➢ **Grid Automation**: The integration of digital technologies and automation into power grids enhances reliability, minimizes losses, and enables the efficient distribution of electricity.

d. **Carbon Capture and Storage (CCS):** Technologies that capture carbondioxide emissions from power plants and industrial processes and store them under ground to mitigate green house gas emissions.

e. **Electric Vehicle technology (EVs):** EVs are becoming more prevalent due to advancements in battery technology, charging infrastructure, and vehicle design. They contribute to reducing emissions in the transportation sector.

f. **Hydrogen Fuel Cells:** Hydrogen fuel cells convert hydrogen into electricity, offering a clean alternative for transportation and energy generation.

g. **Artificial Intelligence (AI) and data analytics:** AI is used to optimize energy generation and consumption, predict maintenance needs, and improve grid management for greater efficiency and sustainability.

h. **Advanced Materials:** New materials, such as lightweight composites and super conductors, are being developed to enhance the efficiency and performance of energy systems.

i. **Energy Internet of Things (IoT):** IoT sensors and devices enable real-time monitoring and control of energy assets, improving energy management and grid reliability.

j. **Micro grids and Decentralized Energy:** Micro grids allow communities and businesses to generate and manage their own electricity locally, providing resilience and the ability to integrate renewable.

## Technological Developments in Manufacturing Sector:

Manufacturing sector has witnessed significant technological advancements that have transformed the way products are designed, produced, and delivered. These technologies have improved efficiency, quality, and flexibility in manufacturing processes. Here are some key technologies in the manufacturing sector:

1. **Additive Manufacturing (3DPrinting):** Additive manufacturing technologies create three-dimensional objects layer by layer, enabling rapid prototyping, customization, and the production of complex geometries.
2. **CNC Machining and Robotics:** Computer Numerical Control (CNC) machines and industrial robots are used for precision machining, welding, assembly, and material handling, enhancing speed and accuracy.
3. **Automation and Industry 4.0:** The integration of automation, IoT devices, and data analytics in manufacturing processes, known as Industry 4.0, allows for real-time monitoring, predictive maintenance, and adaptive production.
4. **Artificial Intelligence (AI) and Machine Learning:** AI and machine learning are applied to optimize production processes, quality control, and supply chain management. They can improve production efficiency and decision-making.
5. **Digital Twins:** Digital twins are virtual replicas of physical products, processes, or systems. They help in simulating, monitoring, and optimizing manufacturing operations and product performance.
6. **Advanced Robotics and Cobots:** Collaborative robots (cobots) work alongside humans, improving efficiency and safety in tasks like assembly, packaging, and material handling.
7. **Advanced Materials and Composites:** Innovative materials, such as carbon fiber composites and advanced polymers, offer improved strength-to- weight ratios and durability for various applications.
8. **Nano-technology:** Nano-technology enables the development of new materials and coatings with unique properties, enhancing product performance and durability.
9. **IoT and Sensor Technologies:** Internet of Things (IoT) devices and sensors collect data from manufacturing equipment and processes, allowing for

real-time monitoring and predictive maintenance.

10. **Big Data Analytics:** Big data analytics processes the vast amounts of data generated in manufacturing to identify patterns, optimize operations, and make informed decisions.

11. **Supply Chain Technologies:** Technologies like block chain and RFID (Radio-Frequency Identification) enhance supply chain visibility, traceability, and efficiency, reducing lead times and costs.

12. **Augmented Reality (AR) and Virtual Reality (VR):** AR and VR technologies are used for employee training, maintenance, and product design, improving productivity and reducing errors.

13. **Lean Manufacturing and Six Sigma:** Lean and Six Sigma methodologies optimize processes, reduce waste, and improve product quality.

14. **Energy Efficiency Technologies:** Energy-efficient machinery, lighting, and heating/cooling systems reduce energy consumption in manufacturing facilities.

15. **Quality Control and Inspection Technologies:** Advanced inspection systems, including automated vision inspection and non-destructive testing, ensure product quality and consistency.

16. **Flexible Manufacturing Systems:** Systems like flexible manufacturing cells and agile manufacturing enable quick adaptation to changing production needs and customer demands.

## Technological Developments in Automotive Sector:

The automotive sector is a centre of technological innovation, driven by the quest for improved safety, efficiency, sustainability, and connectivity. Here are some key technologies in the automotive sector:

**1.** **Electric Vehicles (EVs):** Electric vehicles use electric motors and batteries to replace or supplement traditional internal combustion engines. EVs are becoming more common and offer reduced emissions and lower operatingcosts.

**2.** **Hybrid Vehicles:** Hybrid vehicles combine internal combustion engines with electric motors to improve fuel efficiency and reduce emissions. There are various hybrid configurations, including plug-in hybrids (PHEVs).

**3.** **Autonomous and Self-Driving Vehicles:** Autonomous vehicles use sensors, cameras, and AI algorithms to navigate and drive without human intervention. These technologies are in development and hold the promise of safer and more convenient transportation.

4. **Advanced Driver Assistance Systems (ADAS):** ADAS includes features like adaptive cruise control, lane-keeping assist, automatic emergency braking, and blind-spot monitoring, enhancing safety and driver convenience.

5. **Connected Vehicles:** Connected cars use internet connectivity and sensors to provide real-time information, navigation, and entertainment. They can also communicate with other vehicles and infrastructure for improved traffic management and safety.

6. **Battery Technology:** Advances in battery technology, such as lithium-ion batteries, are critical for improving the range, charging speed, and overall performance of electric vehicles.

7. **Fuel Cell Vehicles (FCVs):** Fuel cell vehicles use hydrogen to generate electricity and power electric motors. FCVs produce zero emissions and offer longer ranges compared to many battery electric vehicles.

8. **Lightweight Materials:** The use of lightweight materials such as carbon fiber, aluminium, and high-strength steel helps improve fuel efficiency andreduceemissions without compromisingsafety.

9. **Advanced Manufacturing Techniques:** Advanced manufacturing processes, like 3Dprinting and automation, are used to stream line production, reduce waste, and improve quality.

10. **Energy-Efficient Engines:** Traditional internal combustion engines continue to evolve, becoming more fuel-efficient and producing fewer emissions.

11. **Augmented Reality (AR) and Heads-Up Displays (HUDs):** AR and HUD technologies provide drivers with important information, such as navigation instructions, speed and alerts, without taking their eyes off the road.

12. **Infotainment Systems:** Modern vehicles feature advanced infotainment systems with touch screens, voice recognition, smart phone integration, and entertainment options.

13. **Wireless Charging:** Wireless charging technology for electric vehicles eliminates the need for physical connectors, making charging more convenient.

14. **Eco-Friendly Manufacturing Practices:** Car manufacturers are adopting sustainable and eco-friendly practices, such as using recycled materials and reducing water and energy consumption in production.

15. **Emissions Reduction Technologies:** Technologies like exhaust gas

recirculation (EGR), selective catalytic reduction (SCR), and diesel particulate filter shall produce emissions from internal combustion engines.

These technologies collectively contribute to making vehicles safer, more environmentally friendly, and technologically advanced. The automotive sector continues to evolve rapidly as it embraces these innovations to meet changing consumer preferences and regulatory requirements.

## Technological Developments in Aerospace Sector:

The aerospace sector is at the fore front of technological innovation, driven by the pursuit of safer, more efficient, and more capable aircraft and spacecraft. Here are some key technologies in the aerospace sector:

1. **Advanced Materials:** Light weight composites, carbon-fiber-reinforced materials, and advanced alloys are used to reduce weight and increase structural integrity in aerospace components.
2. **Jet Engines and Propulsion Systems:** High-bypass turbofan engines and advanced propulsion technologies improve fuel efficiency and reduce emissions in commercial aircraft.
3. **Supersonic and Hypersonic Flight:** Technologies for supersonic and hypersonic flight enable faster travel with applications in commercial aviation and military defence.
4. **Electric and Hybrid Aircraft:** Electric and hybrid propulsion systems are being developed for smaller aircraft to reduce emissions and noise pollution.
5. **Aircraft Design and Aerodynamics:** Computational fluid dynamics (CFD) and wind tunnel testing are used to optimize aircraft design, leading to more aerodynamic and fuel-efficient shapes.
6. **Fly-by-Wire Systems:** Fly-by-wire technology replaces traditional mechanical flight controls with electronic systems, allowing for greater precision and control in aircraft maneuvering.
7. **Unmanned Aerial Vehicles (UAVs):** UAVs, or drones, are used for a variety of applications, including surveillance, mapping, delivery, and agriculture.
8. **Space Launch Systems:** Advancements in space launch technology enable or e frequent and cost-effective access to space.

9. **Reusable Rockets:** Companies like Space-X have developed reusable rocket technology, reduced the cost of space access and made space tourism moreviable.

10. **Satellite Technology:** Miniaturization and advancements in satellite technology have led to a proliferation of small satellites for communication, Earth observation, and scientific research.

11. **Space Exploration Technologies:** Technologies like Mars rovers, space telescopes, and interplanetary spacecraft have expanded our understanding of the cosmos.

12. **Space Tourism:** Private companies are developing space craft for commercial space tourism, making it possible for civilians to travel to space.

13. **Aircraft and Space craft Connectivity:** High-speed internet and communication technologies enable in-flight connectivity and real-time data transmission between aircraft and ground stations.

14. **Space Mining:** The concept of mining resources from asteroids and other celestial bodies is being explored, with potential applications for future space missions and Earth resource sustainability.

15. **Environmental Sustainability:** Research and development efforts are focused on reducing aviation emissions through sustainable aviation fuelsand electric/hybridpropulsion.

16. **Aircraft Health Monitoring:** Sensors and data analytics are used to monitor the health and performance of aircraft systems in real time, enhancing safety and maintenance efficiency.

17. **Autonomous Flight and AI:** AI and machine learning algorithms are employed to enhance autonomous flight capabilities, including autonomous drones and self-flying aircraft.

These technologies collectively drive advancements in aerospace, enabling safer, more efficient, and more sustainable air and space travel. The aerospace sector continues to evolve rapidly as it embraces these innovations to meet the demands of the future.

## Technological Developments in Marine Sector:

The marine sector, which encompasses maritime transportation, off shore industries, and marine science, relies on various technologies to enhance safety, efficiency, and environmental sustainability. Here are some key technologies in the marine sector:

1. **Ship Design and Construction:** Advanced Computer-Aided Design (CAD) software and simulation tools are used for designing ships and optimizing hull shapes for fuel efficiency and stability.
2. **Alternative Fuels:** The adoption of alternative fuels like liquefied natural gas (LNG) and hydrogen aims to reduce emissions from maritime transportation.
3. **Propulsion Systems:** Propulsion technologies include highly efficient diesel engines, gas turbines, and electric propulsion systems to power ships.
4. **Navigation and Positioning Systems:** Global Navigation Satellite Systems (GNSS) and dynamic positioning systems enhance vessel navigation and station-keeping accuracy.
5. **Automation and Autonomous Ships:** Automation and autonomous technologies enable unmanned or remotely operated vessels for tasks like surveying, research and cargo transport.
6. **Ballast Water Management:** Technologies for treating and managing ballast water help prevent the spread of invasive species and protect marine ecosystems.
7. **Under water Vehicles:** Remotely Operated Vehicles (ROVs) and Autonomous Under water Vehicles (AUVs) are used for off shore exploration, research and subsea maintenance.
8. **Sonar and Acoustic Technologies**: Sonar systems are crucial for mapping the sea floor, detecting under water objects and studying marine life.
9. **Marine Renewable Energy:** Technologies like tidal energy turbines, wave energy converters, and floating wind turbines harness the power of the ocean for electricity generation.
10. **Ocean Observation and Monitoring:** Buoy networks, satellites and autonomous under water sensors collect data on ocean currents, temperature, and weather patterns for research and forecasting.
11. **Ship Safety and Navigation Aids**: Advanced radar, AIS (Automatic Identification System), and collision avoidance systems improve ship safetyand navigation.
12. **Ice breaker Technology:** Ice breakers use reinforced hull sand powerful engines to navigate through ice-covered waters, opening up Arctic shipping

routes.

13. **Environmental Monitoring and Protection:** Technologies like oil spill detection systems and marine pollution control measures aim to safe guard marine ecosystems.
14. **Maritime Communication and Connectivity:** High-speed satellite communication systems enable real-time data transfer, navigation and communication for ships at sea.
15. **Sustainable Fishing Practices:** Technologies like sonar fish finders, GPS- based tracking, and responsible fishing practices help maintain fish stocks and reduce over fishing.
16. **Ship Emissions Reduction Technologies:** Exhaust gas cleaning systems (scrubbers), shore power connections, and fuel-efficient ship designs contribute to reducing emissions from vessels.
17. **Ship Recycling and Sustainability:** Technologies for environmentally friendly ship recycling and sustainable shipbuilding practices are evolving to reduce the environmental impact of the industry.
18. **Marine Biotechnology:** Research in marine biotechnology explores the use of marine organisms for pharmaceuticals, bio-plastics and other applications.

These technologies collectively contribute to safer, more efficient, and more environmentally sustainable marine operations, whether in shipping, off shore energy production, scientific research, or conservation efforts. The marine sector continues to evolve and adapt to emerging challenges and opportunities in the maritime industry.

# Engineering Materials

## Introduction:

Engineering materials refers to the group of materials that are used in the construction of man-made structures and components. The primary function of an engineering material is to withstand applied loading without breaking and without exhibiting excessive deflection.

Most engineering materials can be classified into one of these basic categories.

1. Metals
2. Ceramics
3. Polymers
   - Their chemistries are different, and their mechanical and physical properties are different.
   - In addition, there is a fourth category:
4. Composites, a non homogeneous mixture of the other three types, rather than a unique category

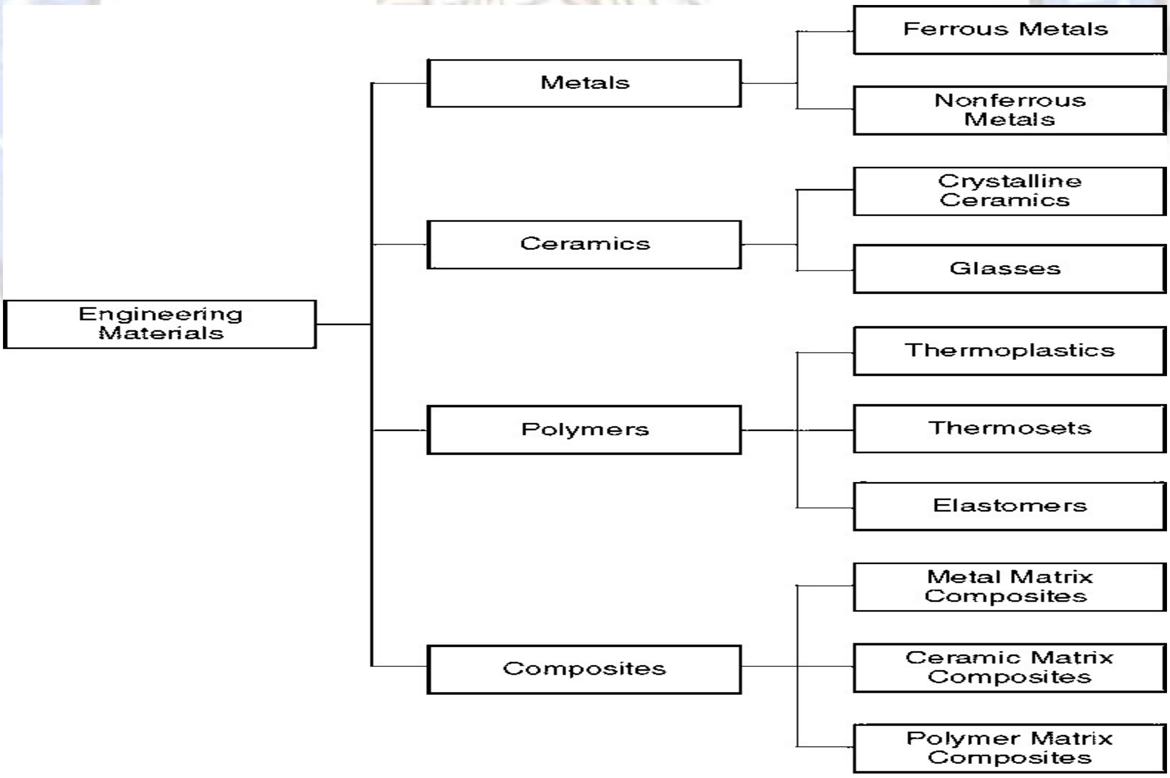



**Fig. Classification of materials**

## Sub Classification of the Metals:

Metals are further sub classified as ferrous metals and non-ferrous metals.

**Ferrous metals**

Iron is the primary component of the ferrous metals, such as cast iron, wrought iron, and steel.

**Non-Ferrous Metals**

The term "non-ferrous metals" refers to materials with a primary component other than iron, such as copper, aluminium, brass, tin, zinc, etc.

Physical, chemical, and mechanical qualities are crucial factors that influence how useful a material is.

## Properties of Metals:

**Physical Properties of Metals**

The metal's physical properties include melting point, density, electric and thermal conductivity, colour, and size.

**Mechanical Properties of Metals**

The ability of a material to with stand loads and mechanical forces is referred to as a material's mechanical properties. Strength, stiffness, elasticity, plasticity, ductility, brittleness, malleability, toughness, resilience, creep, and hardness are the mechanical properties of metal.

1. **Strength:** It is the ability of a material to resist the externally applied forces without breaking or yielding.
2. **Stress:** The internal resistance offered by a part to an externally applied force is called stress.
3. **Stiffness:** It is the ability of a material to resist deformation under stress.
4. **Elasticity:** It is the property of a material to regain its original shape after deformation when the external forces are removed.
5. **Plasticity:** It is property of a material which retains the deformation produced under load permanently.
6. **Brittleness:** It is the property of breaking of a material with little permanent distortion.
7. **Malleability:** It is the property of which permits materials to be rolled or hammered into thin sheets.
8. **Toughness:** It is the property of a material to resist fracture due to high impact loads.

9. **Machinability:** It is the property of a material which refers to a relative case with which a material can be cut.

10. **Resilience:** It is the property of a material to absorb energy and to resist shock and impact loads.

11. **Creep:** When a part is subjected to a constant stress at high temperature for a long period of time.

12. **Fatigue:** When a material is subjected to repeated stresses, it fails at stresses below the yield point stresses.

13. **Hardness:** It also means the ability of a metal to cut another metal.

## Ferrous Metals:

The metals classified as ferrous have iron as their primary element. The ferrous metals commonly used in engineering practice are **cast iron, wrought iron, steels and alloy steels**.

Pig iron, which is produced by smelting iron ore with coke and limestone in a blast furnace, serves as the primary raw material for all ferrous metals. **Cast Iron**

In a cupola furnace, pig iron is re-melted with coke and limestone to produce cast iron.

- It is primarily an alloy of iron and carbon.
- Cast iron has a carbon percentage that ranges from1.7%to4.5%.
- Small amounts of silicon, manganese, phosphorus, and sulphur are also present.
- Cast iron has qualities such as low cost, good casting characteristics, high compressive strength, wear resistance, and great machinability that make it a valuable material for engineering applications.

**Types of Cast Iron**

1. **Grey cast iron:** The grey colour is due to fact that the carbon is in the form of graphite (known as cementite).

**Compositions**

Carbon 3 to 3.5%; Silicon 1to 2.75%; Manganese 0.40 to1.0%; Phosphorous 0.15 to 1%; Sulphur 0.02 to 0.15%; and the remaining is iron.

**Properties**

- It has a low tensile strength, high compressive strength and no ductility.
- It can be easily machined.
- A very good property of grey cast iron is that the free graphite in its structure acts as a lubricant.

**Applications**

The grey iron castings are widely used for machine tool bodies, automotive cylinder blocks, heads, housings, fly-wheels, pipes and pipe fittings and agricultural implements.

**2. White cast iron**

The white colour is due to fact that it has no graphite and whole of the carbon is in the form of carbide (known as cementite).

**Compositions:**

Carbon = 1.75 to 2.3%; Silicon = 0.85 to 1.2%; Manganese = less than 0.4%; Phosphorus -less than 0.2%; Sulphur = less than 0.12%, and the remaining isiron.

**Properties**

- It has a high tensile strength
- It has low compressive strength.

**Applications**

The white cast iron can be utilized for car wheels, grain-crushing rolls, and jaw crusher plates.

**3. Malleable Cast Iron**

A heat-treated iron-carbon alloy known as malleable cast iron solidifies in the as-cast condition with a graphite-free structure, meaning that all of the carbon is present in the cementite form ($Fe_3C$).

**Compositions**

Carbon =2.16-2.90%; Silicon=0.90-1.90%; Manganese=0.15-1.25%; Sulphur =0.02-0.20%; Phosphorus =0.02-0.15% and the remaining is iron.

**Properties**

- While still hard, malleable iron is less brittle than white cast iron and has higher flexibility than grey cast iron.
- It will cast better than several other materials, including white cast iron, even though it does not cast as easily as grey cast iron.

**Applications:**

The malleable iron can be utilized for fence components, piping fixtures, agriculture machinery, house wares, tiny machine components, fashion jewellery, etc.

**4. Nodular Cast Iron**

Nodular Cast Iron, also known as ductile iron, ductile cast iron, spheroidal graphite iron, and spheroidal graphite cast iron, is graphite-rich **cast iron**.

To encourage the presence of carbon in spherical graphite, add a tiny amount of spheroidizing agents, such as magnesium, calcium, and rare earth elements, and graphite agents, such as ferrosilicon and calcium silicon alloy, to molten iron before pouring.

**Compositions:**

Carbon = 3.27–3.91%, Silicon = 2.23–2.56%, Manganese = 0.05–0.09%, Chromium = 0.00–0.28 %, molybdenum = 1.87–2.13 %, and Nickle=0.66–1.05 %.

**Properties**

- Exhibit high strength, flexibility, durability, and elasticity due to their unique microstructure.
- It can be bent, twisted, or deformed without cracking because it often contains more than 3%carbon.

**Applications**

- Car engine parts like bushings, differential shell, and steering parts like control arm shafts, crank shafts and even gears.
- Pressure pipes and fittings, various types of joints like push-on joints, mechanical joints, and flanged joints.
- Pulleys and brackets that are needed by the agricultural industry, paper manufacturing units, etc.

**5. Alloy Cast Iron**

The alloy cast iron is produced by adding alloying elements like nickel, chromium, molybdenum, copper and manganese in sufficient quantities. The alloy cast iron has special properties like increased strength, high wear resistance, corrosion resistance or heat resistance. The alloy cast irons are extensively used for automobile parts like gear, cylinders, pistons, piston rings, crankcases, crankshafts, camshafts, sprockets, wheels, pulleys, brake drums and shoes, parts of crushing and grinding machinery etc.

**Wrought Iron**

It is the purest iron which contains at least 99.5% iron but may contain up to 99.9% iron.

The typical composition of a wrought iron is Carbon-0.020%, Silicon = 0.120%, Sulphur = 0.018%, Phosphorus -0.020%, Slag =0.070%, and the remaining is iron.

- The wrought iron is a tough, malleable and ductile material.
- It cannot stand sudden and excessive shocks.
- It can be easily forged or welded.
- It is used for chains, crane hooks, railway couplings, water and steam pipes.

**Steel**

It is an iron-carbon alloy with a maximum carbon concentration of 1.5%. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of steel. Other elements e.g., silicon, sulphur, phosphorus and manganese are also present to greater or lesser amount to impart certain desired properties to it.

The plain carbon steels varying from 0.06% carbon to 1.5% carbon are divided into the follow types depending upon the carbon content.

Steel is classified into four groups:

1. Carbon steels
2. Alloy steels
3. Stainless steels
4. Tool steels

**1. Carbon steels**

The plain carbon steels varying from 0.06% carbon to 1.5% carbon are divided into the follow types depending upon the carbon content.

- Dead mild steel- up to 0.15% carbon
- Low carbon or mild steel-0.15% to 0.45% carbon

- Medium carbon steel-0.45%to 0.8% carbon
- High carbon steel -0.8% to 1.5%carbon

- **Dead Mild Steels: Dead Mild Steel** has a carbon content of between 0.05% and 0.15%. This gives **Dead Mild Steel** the property of good Ductility and the ability to be easily armed.

Some of the uses of **Dead Mild Steel** are: Tin plate, Car Bodies, Chains, Nails, Thin Wire, etc.

- **Low-carbon steel:** Low-carbon steel, also known as mild steel or plain carbon steel, is a type of steel that contains a relatively low percentage of carbon compared to other types of steel. The carbon content in low-carbon steel typically ranges from 0.15% to 0.45%. Applications of low carbon steels are shown in below fig.

**Fig. Applications of low carbon steel**

**Properties**

➢ **Ductility:** Low-carbon steel is highly ductile, meaning it can be easily drawn, bent, or formed without breaking.

➢ **Weldability**: It can be welded easily, making it suitable for a wide range of fabrication processes.

➢ **Machinability**: Low-carbon steel can be machined and cut with relative ease.

➢ **Strength**: While not as strong as high-carbon or alloy steels, it still has sufficient strength for many applications.

➢ **Cost-effectiveness**: Low-carbon steel is often more affordable than higher carbon and alloy steels.

**Applications**

➢ **Construction:** It is used for structural components in buildings and bridges.

➢ **Automotive industry**: Low-carbon steel is used in the manufacture of car bodies, chassis, and other parts.

➢ **Pipes and tubing**: It is commonly used for water and gas pipe lines.

➢ **Sheet metal**: Low-carbon steel is used for the production of sheet metal products. Nails, screws, and bolts: It is often used to make fasteners.

➢ **Cookware and appliances**: Low-carbon steel is used for items like pots, pans, and house hold appliances.

➢ **Wire products**: It is used to make wire for various applications.

- **Medium Carbon Steel:** Medium Carbon Steel is much stronger than Mild Steel. Its Hardness and Strength can be increased by Heat Treatment, but the amount of improvement depends on the carbon content of the steel. Medium Carbon Steels contain between 0.35% and 0.5%carbon. Where stresses cannot be handled by mild steel, medium carbon steel is typically employed. Uses of medium carbon steel include vehicle axels, garden tools, rail tracks, and so forth. Applications of medium carbon steel is shown in below fig.

**Fig. Applications of medium carbon steel**

- **High Carbon Steel:** The carbon percentage of high carbon steel ranges from 0.55 to 1.5%. It has good wear resistance and hardness. High carbon steel can be used for a variety of things, including chisels, files, drills, springs, and taps. Applications of high carbon steels are shown in below fig.

**Fig. Applications of high carbon steel**

**2. Alloy steels**

Steel is combined with additional alloying components like nickel, copper, chromium, and/or aluminium to create alloy steels. The strength, ductility, corrosion resistance, and machinability of the steel are all improved by combining these constituents. Pipes, tubes, plates, sheets, coils, bars, rods, wires, forged fittings, butt weld fittings, flanges, fasteners, and more can all be formed from alloys steel. Applications of alloy steels are shown in below fig.

**Fig. Applications of alloy steel**

**3. Stainless Steel**

Steel with a chromium content of more than 10.5%, as well as various other elements in smaller quantities, is considered to be stainless. Applications of stainless steels are shown in below fig.

**Fig. Applications of stainless steels**

**Properties**

- Corrosion resistant
- High tensile strength

- Very durable
- Temperature resistant
- Easy formability and fabrication
- Low-maintenance (long lasting)
- Attractive appearance
- Environmentally friendly (recyclable)

**Applications**

- Culinary uses
- Kitchen sinks
- Cutlery
- Cookware
- Surgical tools and medical equipment
- Surgical implants
- Auto bodies
- Rail cars
- Aircraft

**4. Tool Steel**

Tool steel can refer to a variety of carbon and alloy steels which are commonly used to make tools. Carbon content between 0.7% and 1.5%.

**Properties**

- Distinctive hardness
- Resistance to abrasion
- Ability to hold a cutting edge
- Red-hardness
- Machinability
- Grindability
- Tolerances
- Polishability

**Applications**

- Drills, end mills, taps, and turning tools.
- Gears, shafts, spindles, and bearings.
- Chisels, saw blades and plane irons.

## Non-ferrous Materials:

Non-ferrous materials are metals and alloys that do not contain significant amounts of iron (ferrous), or if they do, the iron content is negligible. These materials have a variety of properties and are used in a wide range of applications. Some common non-ferrous materials include:

1. **Aluminium:** Aluminium is one of the most abundant non-ferrous metals. It is light weight, corrosion-resistant, and has good electrical and thermal conductivity. It's used in aeronautics, construction, packaging, and electrical wiring.
2. **Copper:** Copper is an excellent conductor of electricity and heat. It's used in electrical wiring, plumbing, and for making various alloys, such as brass and bronze.
3. **Brass:** Brass is an alloy of copper and zinc. It's known for its yellowish colour and corrosion resistance. Brass is used in musical instruments, plumbing fixtures, and decorative items.
4. **Bronze:** Bronze is an alloy of copper and tin, but it can also contain other elements like aluminum, silicon, and manganese. It's strong, corrosion-resistant, and often used for sculptures, bearings, and marine applications.
5. **Lead:** Lead is a dense and malleable metal. It's been widely used in the past for pipes, solder, and shielding against radiation, though its use has declined due to environmental concerns.
6. **Tin:** Tin is a soft and malleable metal. It's used to coat other metals to prevent corrosion (tin-plating), and it's a primary component of solder.
7. **Nickel:** Nickel is known for its resistance to corrosion and high- temperature environments. It's used in various alloys, including stainless steel and nickel-based super alloys for aerospace and industrial applications.
8. **Titanium:** Titanium is a lightweight and corrosion-resistant metal used

in aerospace, medical implants, and high-performance sports equipment.

9. **Magnesium:** Magnesium is light weight and has excellent strength-to- weight ratio. It's used in aerospace, automotive, and electronic applications.
10. **Zinc:** Zinc is commonly used as a protective coating for steel and iron (galvanization). It's also used in batteries, die-casting, and alloys like brass.
11. **Precious Metals:** Precious metals like gold, silver, and platinum are non-ferrous and are highly valued for their rarity and various industrial applications, including jewelry, electronics, and catalytic converters.
12. **Tungsten:** Tungsten has an extremely high melting point and is used in applications requiring high-temperature resistance, such as light bulb filaments and aerospace components.

## Ceramics:

Ceramics are a class of materials that are known for their unique properties, which include high melting points, excellent electrical and thermal insulation, hardness, and chemical resistance. They are typically non-metallic and often composed of inorganic compounds, although some ceramics may contain organic components. Ceramics find a wide range of applications across various industries due to their diverse properties.

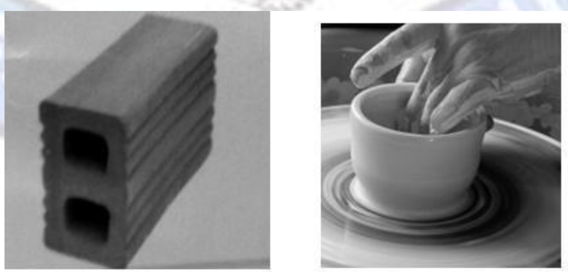
**Composition:**

Ceramics are primarily composed of inorganic materials, such as oxides, nitrides, carbides, and silicates. Common elements in ceramics include silicon, aluminum, oxygen, and nitrogen.

**Types of Ceramics:**

**Traditional Ceramics:** These include clay-based products like pottery, porcelain, and bricks.

**Fig. Applications of ceramics**



**Advanced Ceramics:** These are engineered ceramics with specific properties. These are used in cutting tools and bearings, capacitors and semi conductors), and dental and orthopedic implants.

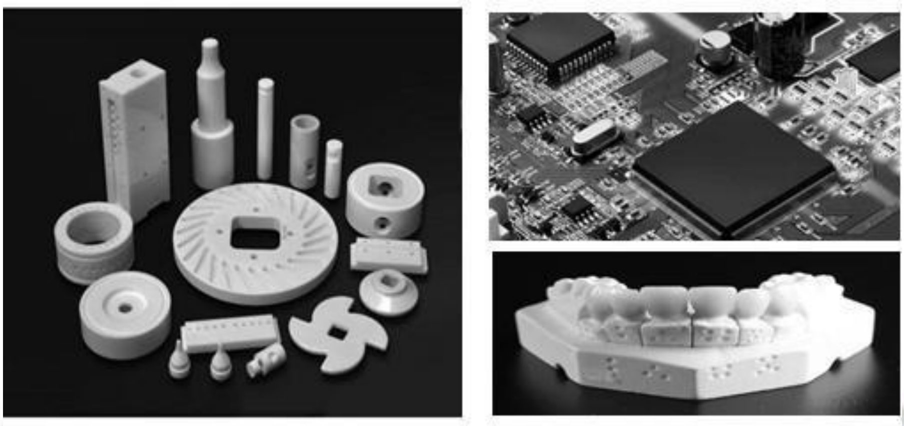


**Fig. Applications of advanced ceramics**

**Properties of Ceramics:**

1. **High Temperature Resistance:** Ceramics can withstand extremely high temperatures without melting or deforming, which makes them suitable for applications like kiln linings, furnace components, and jet engine parts.
2. **Hardness:** Ceramics are often very hard and resistant to wear, which is advantageous for cutting tools, grinding wheels, and armour materials.
3. **Electrical Insulation:** They have excellent electrical insulation properties and are used in insulators, electrical components, and circuit boards.
4. **Thermal Insulation:** Ceramics have low thermal conductivity, making the mi deal for applications like insulating tiles on space craft or refractory materials in furnaces.
5. **Chemical Resistance:** Many ceramics are highly resistant to chemical corrosion, making them suitable for chemical processing equipment.
6. **Brittleness:** Ceramics are generally brittle and can fracture under mechanical stress, which can be a limitation in some applications.
7. **Manufacturing:** Ceramics are typically formed through processes like firing or sintering, where powders or clay-like materials are heated to high temperatures to create a solid, often crystalline structure.

**Applications of Ceramics:**

1. **Structural:** Ceramics are used in aerospace components, cutting tools, bearings, and automotive parts.
2. **Electronics:** They are used in capacitors, insulators, and semi conductor components.

3. **Medical:** Ceramics are used in dental implants, orthopedic implants, and medical tools.
4. **Energy:** Ceramics are used in fuel cells, heat exchangers, and nuclear fuel rods.
5. **Construction:** Ceramics are used in tiles, bricks, and insulating materials.
6. **Art and Decor:** Ceramics are used for pottery, porcelain, and decorative items.

**Limitations:**

Despite their many advantages, ceramics can be challenging to work with due to their brittleness and the difficulty of machining and shaping them. Additionally, their high cost can be a limitation in some applications.

## Composites:

Composites are materials made by combining two or more distinct materials to create a new material with enhanced properties. Typically, one material, called the matrix, is combined with reinforcement materials to create a composite material. The resulting composite material often exhibits improved strength, stiffness, durability, or other desirable characteristics compared to its individual components. Composites have a wide range of applications across various industries.

**Composition:**

1. **Matrix Material:** The matrix material is the primary component of the composite and holds the reinforcement materials together. It can be a polymer, metal, ceramic, or even another composite material.
2. **Reinforcement Materials:** Reinforcements are usually strong and stiff materials that are embedded within the matrix to enhance specific properties of the composite. Common reinforcement materials include fiber glass, carbon fibre and natural fibres.

**Types of Composites:**

1. **Polymer Matrix Composites (PMCs):** These composites use polymer matrices, such as epoxy, polyester, or thermoplastics. They are light weight and commonly used in aerospace, automotive, and sports equipment.
2. **Metal Matrix Composites (MMCs):** These composites have a metal matrix, such as aluminium or magnesium, reinforced with materials like silicon carbide or alumina. They offer high strength and stiffness and are

used in aerospace and automotive industries.

3. **Ceramic Matrix Composites (CMCs):** CMCs use ceramic matrices and ceramics or carbon fibres as reinforcements. They are known for their high-temperature resistance and are used in aerospace and gas turbine engines.
4. **Carbon-Carbon Composites (C/C):** These composites consist of carbon fibers within a carbon matrix. They are extremely lightweight and have high-temperature resistance, making them suitable for aerospace and high-performance applications.
5. **Natural Fiber Composites:** These composites use natural fibers like jute, hemp, or flax as reinforcements in polymer matrices. They are eco- friendly and used in automotive interior components and construction materials.

**Properties of Composites:**

1. **High Strength:** Composites can be designed to have exceptional strength-to-weight ratios.
2. **Stiffness:** They often exhibit high stiffness, making them suitable for structural applications.
3. **Lightweight:** Composites are typically lightweight, which is advantageous in aerospace and automotive industries.
4. **Corrosion Resistance:** Depending on the matrix and reinforcement materials, composites can be highly corrosion-resistant.
5. **Tailored Properties:** Composites can be engineered to have specific properties, such as electrical conductivity, thermal insulation, or electromagnetic shielding.

**Manufacturing of Composites:**

1. **Layup:** In this process, layers of reinforcement materials are stacked and impregnated with the matrix material.
2. **Injection Moulding:** Molten matrix material is injected into a mould containing reinforcement materials.
3. **Pultrusion:** Continuous fibres are pulled through a die and impregnated with resin to create a composite shape.
4. **Filament Winding**: Fibers are wound onto a mandrel in a specific pattern, and resin is applied to create composite tubes or cylindrical shapes.

**Applications of Composites:**

1. **Aerospace:** Composites are used in aircraft components like wings, fuselages, and interior structures.
2. **Automotive:** They are used for light weight body panels, suspension components, and interior parts.
3. **Sporting Goods:** Composites are found in tennis rackets, golf clubs, and bicycles.
4. **Construction:** They are used in bridge components, reinforcement for concrete and architectural elements.
5. **Marine:** Composites are used in boat hulls and masts.
6. **Renewable Energy:** Wind turbine blades often in corporate composite materials.

## Smart Materials:

Smart materials, also known as intelligent or responsive materials, are materials that exhibit adaptive and dynamic responses to external stimuli, such as temperature changes, mechanical forces, electrical fields, or magnetic fields. These materials can change their properties or behaviour in a controlled and predictable manner when subjected to specific conditions. Smart materials have a wide range of applications in various industries, including aerospace, automotive, healthcare, and electronics. Here are some common types of smart materials and their applications:

**Shape Memory Alloys (SMAs):**

**Example:** Nitinol (Nickel-Titanium alloy)

**Properties:** SMAs can "remember" their original shape and return to it when heated (shape memory effect).

**Applications:** Used in medical devices like stents, eye glass frames, and actuators in robotics and aerospace.

**Piezoelectric Materials:**

**Example:** Lead zircon atetitanate (PZT)

**Properties:** Piezoelectric materials generate an electrical charge when subjected to mechanical stress and can also deform when subjected to an electrical field (the piezoelectric effect).

**Applications:** Used in sensors, actuators, and energy harvesting devices. Commonly found in ultra sound transducers and vibration sensors.

**Electro active Polymers (EAPs):**

**Example:** Dielectric elastomers, conducting polymers

**Properties:** EAPs can change their shape or size in response to an electric field or generate an electric field when mechanically deformed.

**Applications:** Used in soft robotics, haptic feed back devices, and artificial muscles.

**Thermo chromic Materials:**

**Example:** Liquid crystals, certain dyes

**Properties:** Thermo chromic materials change colour or transparency in response to temperature changes.

**Applications:** Used in mood rings, thermometers, and smart windows that controls the amount of sunlight entering a building.

**Hydrogels:**

**Properties:** Hydrogels can absorb and release water, changing their volume and properties in response to changes in humidity or pH.

**Applications:** Used in drug delivery systems, contact lenses, and tissue engineering.

**Smart Textiles:**

**Examples:** Fabrics embedded with conductive threads, shape memory textile composites

**Properties:** These textiles can sense and respond to environmental conditions or user input.

**Applications:** Used in sports clothing for monitoring performance, military uniforms with adaptive camouflage, and healthcare garments for monitoring vital signs.

**Self-healing Materials:**

**Examples:** Polymers with micro capsules of healing agents, concrete with embedded bacteria.

**Properties:** These materials can repair damage autonomously when subjected to mechanical or environmental stress.

**Applications:** Used in automotive coatings, aerospace components, and construction materials to increase durability and reduce maintenance.

# UNIT – II THERMAL ENGINEERING

## Introduction:

A steam generator or boiler is, usually, a closed vessel made of steel. Its function is to transfer the heat produced by the combustion of fuel (solid, liquid or gaseous) to water, and ultimately to generate steam. The steam produced may be supplied:

1. To an external combustion engine, i.e. steam engines and turbines,
2. At low pressures for industrial process work in cotton mills, sugar factories, breweries, etc., and
3. For producing hot water, which can be used for heating installations at much lower pressures.

### Important Terms for Steam Boilers:

Though there are many terms used in steam boilers, yet the following are important from the subject point of view:

1. **Boiler shell.** It is made up of steel plates bent into cylindrical form and riveted or welded together. The ends of the shell are closed by means of end plates. A boiler shell should have sufficient capacity to contain water and steam.
2. **Combustion chamber.** It is the space, generally below the boiler shell, meant for burning fuel in order to produce steam from the water contained in the shell.
3. **Grate.** It is a platform, in the combustion chamber, upon which fuel (coal or wood) is burnt. The grate, generally, consists of cast iron bars which are spaced apart so that air can pass through them. The surface area of the grate, over which the fire takes place, is called grate surface.
4. **Furnace.** It is the space, above the grate and, below the boiler shell, in which the fuel is actually burnt.
5. **Heating surface.** It is that part of boiler Surface, which is exposed to the fire
6. **Mountings.** These are the fittings which are mounted on the boiler for its proper functioning. They include water level indicator, pressure gauge, safety valve etc. It may be noted that a boiler, cannot function safely without the mountings.

7. **Accessories.** These are the devices, which form an integral part of a boiler, but are not mounted on it. They include super heater, economizer, feed pump etc. It may be noted that the accessories help in controlling and running the boiler efficiently.

## Essentials of a Good Steam Boiler:

Following are the important essentials of a good steam boiler:

1. It should produce maximum quantity of steam with the minimum fuel consumption.
2. It should be economical to install, and should require little attention during operation.
3. It should rapidly meet the fluctuation of load.
4. It should be capable of quick starting.
5. It should be light in weight.
6. It should occupy a small space.
7. The joints should be few and accessible for inspection.
8. The mud and other deposits should not collect on the heating plates.
9. It should comply with safety regulations as laid down in the Boilers Act

## Selection of a Steam Boiler:

The selection of type and size of a steam boiler depends upon the following factors:

1. The power required and the working pressure.
2. The rate at which steam is to be generated.
3. The geographical position of the power house.
4. The fuel and water available.
5. The type of fuel to be used.
6. The probable permanency of the station.
7. The probable load factor.

### Classification of Steam Boilers:

Steam boilers are classified as follows.

1. **According to the relative position of hot gases and water**

✓ **Fire tube boiler**: hot gases generated by the combustion of fuel pass through tubes that are surrounded by water. These are relatively simple.

✓ **Water tube boiler**: Water-tube boilers have water-filled tubes that carry water through the boiler while hot gases from combustion flow over them. These are used in large power generation.

## 2. According to the application of boilers

- ✓ Industrial
- ✓ Commercial
- ✓ Residential boilers

## 3. According to the axis position of the boilers

- ✓ Horizontal
- ☐ Vertical

## 4. Based on circulation of water

- ✓ Natural circulation
- ✓ Forced circulation

## 5. According to number of tubes in the boiler

- ✓ Single tube
- ✓ Multi tube boilers

## 6. According to pressure inside the boiler

- ✓ Low pressure
- ✓ High pressure boilers

## 7. According to the position of furnace

- ✓ Internally fired
- ✓ Externally fired

**Distinguishing between Fire Tube and Water Tube Boilers**

| S.No | Fire Tube Boiler | Water Tube Boiler |
|---|---|---|
| 1 | Hot flue gases pass through tubes and water surrounds them | Water passes through tubes and hot Flue gasses surround them |
| 2 | It requires more floor area for a given output | It requires less floor area for a given output |
| 3 | Overall efficiency is upto75% | Overall efficiency with an Economizer is up to 90% |
| 4 | These are bulky and difficult to transport | These are lighter in weight, hence transportation is not a problem |
| 5 | The drum size is large and damage caused by bursting is large | If any water tube is damaged, it can be easily replaced or repaired. |
| 6 | Load fluctuations cannot be handled | Load fluctuations can be easily handled |

| | | |
|---|---|---|
| 7 | Pressure ranges from17.5 to 24.5 bar | Operating pressure up to 200bar |

| | | |
|---|---|---|
| 8 | Water content: Steam capacity high | Water content: Steam capacity is low |
| 9 | Water does not circulate in a Definite direction | Direction of water circulated is well defined |
| 10 | Ex: Cochran boiler, Lancashire boiler, Scotch boiler, Locomotive boiler. | Ex: Babcok & Wilcox boiler. Stirling boiler, Lamont boiler, Benson boiler. |

## Working principle of Lamont Boiler:

A LaMont boiler is a type of water-tube boiler used for high-pressure steam generation. Invented by Walter LaMont in the 1920s, it features inclined water tubes to promote efficient heat transfer. This design allows for rapid steam production and is commonly employed in power plants and industrial settings for its energy efficiency and reliability.

### LaMont Boiler Construction:

The Lamont Boiler consists of a large cylindrical drum filled with water and connected to a pump. Tubes run from the drum to a steam separator, where water and steam separate. Water is recirculated by the pump, and steam is collected for use. This design promotes efficient heat transfer and high- pressure steam generation.

### Various components of LaMont Boiler are

Feed Pump Grate

Economizer

Circulating Pump Distributing

header Radiant Evaporator

Convective Evaporator Steam

separating drum Superheater

Blower

Air preheater and Combustion

chamber

### Feed Pump:

The feed pump plays a crucial role in the boiler system by supplying feed water and increasing its pressure to facilitate entry into the boiler.

### Grate:

Positioned at the bottom of the furnace, the grate is where coal is introduced for combustion in the combustion chamber.

**Economizer:**

The economizer is a vital component designed to enhance boiler efficiency. Its primary function is to preheat the water using the residual heat from the flue gases generated in the combustion chamber. As part of this process, feed water first passes through the economizer, benefiting from this preheating advantage.

**Circulating Pump:**

Operated by a turbine, the circulating pump functions as a centrifugal pump. It draws steam from the boiler and water from the steam-separating drum, directing it to the distributing header leading to the radiant evaporator section.

**Distributing Header:**

This component features a single inlet and multiple outlet ends, facilitating the distribution of water or steam within the system.

**Radiant Evaporator:**

In the radiant evaporator, water undergoes a phase change from liquid to saturated liquid and then to saturated steam. This transformation is driven by the heat generated from the combustion of fuel, typically coal.

**Convective Evaporator:**

The convective evaporator is where the complete saturation of water into saturated steam occurs.

**Steam-Separating Drum:**

The primary role of the steam-separating drum is to separate steam from water. Subsequently, the steam is directed to the superheater, while the water returns to the circulating pump.

**Superheater:**

As its name implies, the superheater increases the temperature of the steam by supplying additional heat. This process ensures the steam is free from any residual liquid particles, rendering it suitable for driving turbine blades.

**Blower:**

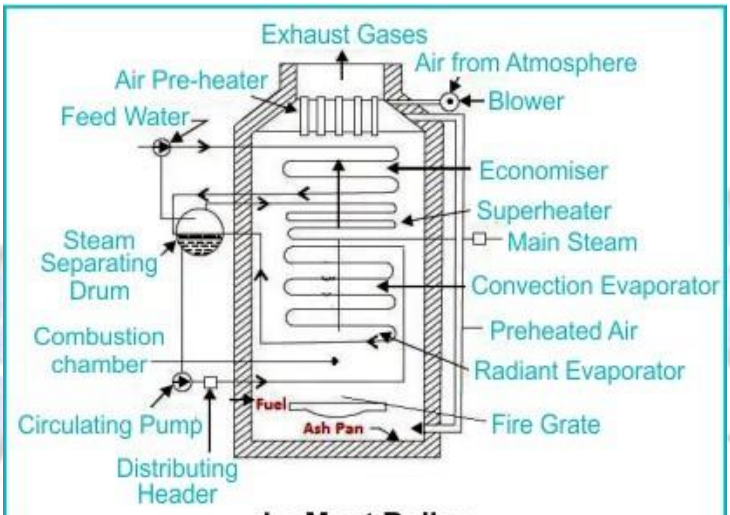
The blower is an external component responsible for drawing in air and directing it to the air preheater.

**Air Preheater:**

Another crucial device for enhancing boiler efficiency, the air preheater, preheats incoming air before delivering it to the combustion chamber.

**Combustion Chamber:**

Within the combustion chamber, coal is burned, generating hot flue gases that serve as the heat source to raise the temperature of the water in the system.




La Mont Boiler

**Working Principle:**

The LaMont Boiler operates on the principle of forced water circulation through the boiler with the assistance of a centrifugal pump. It functions as a high-pressure boiler, typically working above 170bar with a temperature reaching around 773 K.

The working principle of the LaMont Boiler can be described as follows:

- Feedwater Supply: The process begins with the supply of water from a large water tank to the feed pump.
- Economizer: From the feed pump, the water is directed into the economizer. This component increases the boiler's efficiency by preheating the water if heat is available before it enters the combustion chamber.
- Steam Separation: After passing through the economizer, the water enters a steam separator device, where the separation of steam and water takes place.
- Centrifugal Pump Circulation: The separated water is then circulated by a centrifugal pump from the separator drum. A distributor header is in place to control the water level as it enters the boiler.

- Combustion Chamber: Upon entering the combustion chamber, the water is surrounded by flue gases, initiating the heating process.
- Radiant Evaporation: Within the radiant evaporator, a significant portion of the water is converted into steam as it absorbs heat.
- Saturated Steam Production: The remaining water undergoes further transformation into saturated steam. This saturated steam is directed back to the separator drum to separate steam and water.
- Superheating: Following the separation process, the steam is sent to the superheater, where it is further heated to achieve higher temperatures. This superheated steam can then be used for various applications, including electricity generation and more.

**Advantages:**

- Rapid initiation of operation
- Impressive steam generation capacity, approximately 50 tonnes per hour.
- Boasts a high heat transfer rate for optimal performance.
- Demonstrates excellent fuel efficiency, conserving energy resources.
- Requires minimal maintenance efforts, reducing operational costs.

**Disadvantages:**

- Due to its high-pressure and large-capacity design, the LaMont Boiler may not be suitable for low-pressure or small-scale steam generation applications.
- The initial investment for installing can be relatively high.
- Complex design, leading to higher manufacturing and maintenance costs.
- Requires a high water flow rate, which may be difficult to achieve in some applications.

**Applications:**

- LaMont Boilers are commonly used in power plants for electricity generation.
- They find application in industrial processes requiring high-pressure steam.
- They are employed in chemical manufacturing and petrochemical plants.
- Used in ships and marine applications due to their compact design and efficiency.

## Working principle of Babcock and Wilcox Boiler:

The Babcock and Wilcox Boiler, a stationary water-tube boiler, comprises a steam-water drum connected to the uptake and down headers via a short tube, as illustrated. Each down header is equipped with a mud box for efficient mud removal. A coal hopper feeds coal onto a slow-moving chain, while a firebrick baffle wall deflects hot gases, aiding their exit through the chimney. Draught regulation is achieved through dampers operated by a chain and pulley mechanism.

### Parts of Babcock and Wilcox Boiler:

Following are the important parts of Babcock and Wilcox Boiler.

- Water drum
- Down take header
- Uptake header
- Water tubes
- Baffle plates
- Fire door
- Grate
- Mud box
- Feed check valve
- Furnace
- Dampers

These components are discussed in detail in the following lines:

- **Water Drum:** This horizontally oriented drum contains both water and steam and is linked to the uptake header through a short tube located at its rear end.
- **Downtake Header:** Positioned at the rear of the boiler, the downtake header connects the water tubes to the back of the drum and collects water from it.
- **Uptake Header:** Situated at the front of the boiler, the uptake header is affixed to the drum's front end, facilitating the transmission of steam from the water tubes to the drum.
- **Water Tubes:** These tubes serve as conduits through which water transforms into steam. The water tubes in a Babcock and Wilcox boiler are typically inclined at an angle to promote efficient heat transfer and circulation of water. These tubes, having a 10 cm diameter, connect the uptake header to the downtake header.

- **Baffle Plates:** Located within the water tubes, baffle plates redirect hot gases upwards, downwards, and then upwards again before exiting through the chimney. These plates play a crucial role in deflecting hot flue gases.
- **Fire Door:** The fire door is used to ignite solid fuel within the furnace.
- **Grate:** Acting as a platform, the grate is where solid fuel, such as coal, is burned.
- **Mud Box:** Each downtake header is equipped with a mud box to collect and facilitate the removal of settled mud.
- **Feed Check Valve:** This valve is employed to introduce water into the drum.
- **Furnace:** Positioned beneath the uptake header, the furnace is the space where fuel is actively burned.
- **Dampers:** These dampers are controlled by a chain system passing over a pulley to the front of the boiler, regulating the draught to ensure efficient operation.

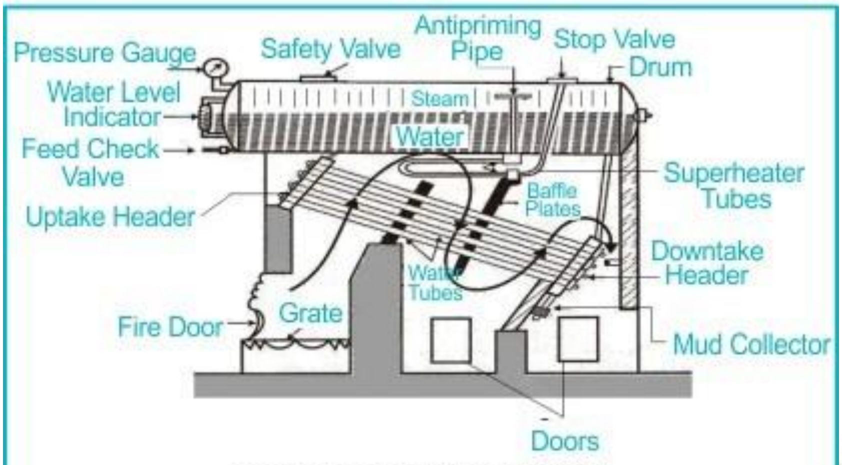
## Working Principle:

Coal is introduced into the grate through the fire door and ignited, causing the resulting hot exhaust gases to rise and flow across the left side of the water tubes. Baffles strategically guide these flue gases in a zig-zag pattern over the water tubes and the superheater. Eventually, the exhaust gases exit through the chimney.

The section of water tubes situated just above the furnace experiences a higher temperature than the rest. Water ascends into the drum through the uptake header, where both steam and water are evenly distributed. Being lighter, steam collects in the drum's upper region, while water from the drum descends through the down header into the water tubes.

This continuous movement of water from the drum to the water tubes, and vice versa, is sustained by convective currents, commonly referred to as "natural circulation." Steam is drawn from the steam space through tubes leading to the superheater, where it undergoes further heating.

For the secure operation of the boiler, essential fittings and devices are incorporated. On the left end of the boiler, you will find the water level indicator and pressure gauge. The stop and steam safety valves are positioned on the upper side of the drum, ensuring safety. Additionally, a blow-off cock is provided to remove accumulated mud and sediment from the mud box periodically.




Babcock and Wilcox Boiler

## Advantages:

- This boiler exhibits exceptional overall efficiency.
- It occupies minimal space, making it a compact choice.
- Damaged tubes can be easily replaced in this boiler.
- It achieves a substantial steam production rate, approximately exceeding 20 tonnes per hour.
- The boiler experiences minimal draught loss, optimizing energy utilization.

## Disadvantages:

- Maintenance expenses for this boiler can be substantial.
- It is not well-suited for use with impure or sediment-laden water, as the accumulation of scale within the tubes can lead to overheating and tube failure. Proper water treatment is essential before introducing water into the boiler.
- This boiler demands a constant supply of feedwater to operate effectively. Even brief interruptions in the water supply can result in overheating. Therefore, strict monitoring of water levels is crucial during the boiler operation.

## Applications:

- Power generation in steam power plants.
- Industrial processes requiring high-pressure steam.
- Marine applications for propulsion and auxiliary power.
- Heating systems in commercial and industrial facilities.
- Used in various industries, such as pulp and paper, chemical, and textile

manufacturing, for steam production.

## Working Principle of Benson Boiler:

The Benson boiler is a high-pressure, drumless water tube steam boiler that operates through forced circulation. It distinguishes itself by introducing feed water at one end and expelling superheated steam at the opposite end. Achieving supercritical pressure (exceeding the critical threshold of 225 bar), the feed pump facilitates the direct transformation of water into steam without the need for boiling. Benson boiler is one of the high-pressure boilers having the unique feature of producing steam at supercritical pressure, which means it operates at a pressure and temperature above the critical point of water, resulting in improved thermodynamic efficiency and power generation capabilities.

### Parts of Benson Boiler:

Benson Boiler consists of the following Main Parts:

- Chamber
- Water Feed Pump
- Blower
- Furnace
- Economizer
- Air Preheater
- Radiant Superheater
- Convection Evaporator
- Convecting Superheater
- Throttle Valve
- Chimney

### Feed Pump:

The Benson boiler employs forced water circulation, and a feed pump is instrumental in delivering water to the boiler at critical pressure.

### Air Preheater:

Before entering the combustion chamber, air undergoes preheating, which significantly enhances the boiler's efficiency.

### Economizer:

Water sourced from the feed pump initially traverses through the economizer. Here, combustion gases are harnessed to preheat the water, contributing to the boiler's overall efficiency.

### Radiant Evaporator:

Subsequently, the water from the economizer proceeds to the radiant evaporator, where heat transfer occurs through radiant methods. This section is situated in close proximity to the combustion chamber.

**Convective Evaporator:**

Within the convective evaporator section, convection is the mechanism through which heat is transferred from flue gases to the water, leading to complete water evaporation.

**Convective Superheater:**

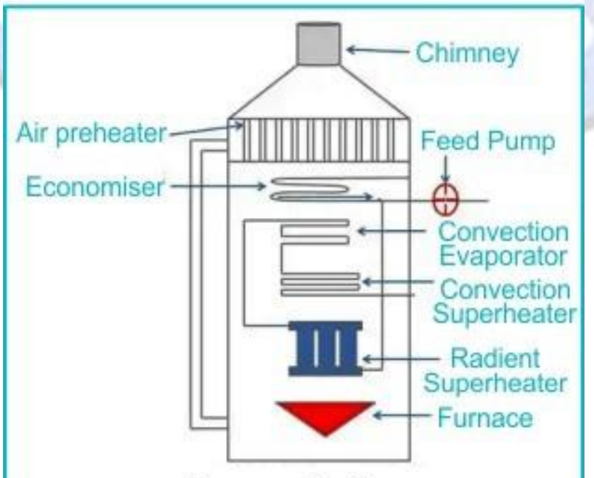
The convective superheater serves as the final chamber in the boiler. Steam flows through this chamber, elevating the steam's temperature. The resulting superheated steam is then extracted for industrial processes.

**Working Principle:**

The diagram illustrates the Benson boiler, a water tube boiler operating on the principle of water's critical pressure, denoting the point where water and gas states are in equilibrium.

In the Benson Boiler, the feedwater flows through the economizer to the furnace's water-cooled walls, absorbing heat through radiation, thereby raising its temperature close to the critical level. Subsequently, it enters the evaporator, potentially undergoing superheating. Finally, the feedwater is directed through the superheater to attain the desired level of superheated steam.

This particular boiler, often referred to as a lightweight boiler, lacks a sizable water and steam drum. It can achieve an impressive thermal efficiency of up to 90%. Typically operating at an average pressure of 250 bar and a capacity of 135 tons per hour, this boiler can be ready for use in just 15 minutes.




Benson Boiler

**Advantages:**

- The absence of a water-steam separator drum in the Benson boiler reduces overall boiler costs.
- The Benson boiler boasts portability, enabling convenient transportation between stations.
- It combines cost-efficiency with enhanced performance, making it an economically attractive choice.
- The quick and seamless startup enables the boiler to reach its maximum load capacity in just 10 minutes.

**Disadvantages:**

- Excessive tube temperatures can lead to inadequate water supply.
- Given its limited storage capacity, precise synchronisation among steam, feedwater, and feed inlet is imperative.
- If impure water is present, the evaporation process can carry salts and solids into the tubes, potentially resulting in significant damage and blockages.
- Managing the boiler for varying loads can pose challenges and complications.
- Continuous inspection is essential to avert the risk of explosions, which may occur due to the supercritical pressure present.

**Applications:**

- Benson boilers are extensively used in modern power plants for efficient steam generation.
- They find application in both fossil fuel-fired and nuclear power plants.
- They play a vital role in industrial processes requiring high-pressure and supercritical steam.
- Benson boilers are utilized in thermal desalination plants to produce fresh water from seawater.

## Working principle of cochran boiler:

The Cochran Boiler is a vertical, multi-tubular boiler equipped with numerous horizontal fire tubes. It offers significantly improved efficiency compared to a standard vertical boiler. It does so by extending the heating surface through multiple fire tubes. The efficiency of the Cochran Boiler ranges from 70% to 75%.

## Parts or Construction of Cochran boiler:

Cochran Boiler consists of the following Parts or Construction:

- Grate
- Fire door
- Ash Pit
- Flue gases
- Flue Pipes
- Combustion Chamber
- Smoke Box
- Chimney
- Water level Indicator
- Man Hole
- Pressure gauge
- Safety Valve
- Steam stop valve
- Anti-priming Pipe
- A blow of valve and others

### Grate:

The grate serves as the fuel entry point, constructed with iron bars segmented into two to three bars per section, allowing ample airflow critical for efficient fuel combustion inside the combustion chamber.

### Fire Door:

The fire door is the gateway for igniting the fuel within the boiler.

### Ash Pit:

Below the grate, the ash pit accumulates ashes generated during combustion.

### Flue Gases:

As fuel combustion commences in the combustion chamber, it produces hot gases, elevating their temperature as more fuel burns. These heated gases, referred to as flue gases, transfer heat to the surrounding water, eventually superheating it.

### Flue Pipes:

Flue pipes play a pivotal role in conveying the hot flue gases from the grate to the combustion chamber, establishing a crucial link in the heat transfer process.

### Combustion Chamber:

Lined with fire bricks on the shell's side to prevent overheating, the combustion chamber accommodates solid fuel, such as coal, and facilitates its combustion, producing high-temperature heat. This heat transfers to the surrounding water, heating it in the process.

**Smoke Box:**

The smoke box serves as a reservoir for storing and releasing smoke into the chimney during the operation of the Cochran boiler. It's typically constructed from riveted or welded steel plates and features a concrete-lined floor for protection against rainwater, hot char, or acid attacks.

**Chimney:**

Positioned atop the boiler, the chimney is connected to the smokebox. It facilitates the release of smoke into the atmosphere once the gases have undergone complete combustion.

**Water Level Indicator:**

Critical to boiler operation, the water level indicator is a measuring instrument that provides information about the water level inside the boiler. It features markings for water level indication, helping prevent potential boiler damage by ensuring proper water levels.

**Man Hole:**

The manhole serves as an access point for boiler specialists to enter and conduct repairs or maintenance when components or the boiler itself are not functioning correctly.

**Pressure Gauge:**

Installed at the front of the boiler, the pressure gauge measures the steam pressure generated within the boiler. It assists in monitoring and controlling the system when pressure levels deviate from the desired range. **Safety Valve:**

Designed to prevent excessive steam pressure, the safety valve opens and releases steam to the atmosphere when pressure exceeds the boiler's designated limit. It typically operates through a spring-controlled mechanism.

**Steam Stop Valve:**

Responsible for regulating the flow of steam outside the boiler, the steam stop valve ensures that only dry saturated steam, free from water particles, is supplied to the intended destination.

**Anti-Priming Pipe:**

The anti-priming pipe serves the purpose of extracting dry, saturated steam from the boiler.

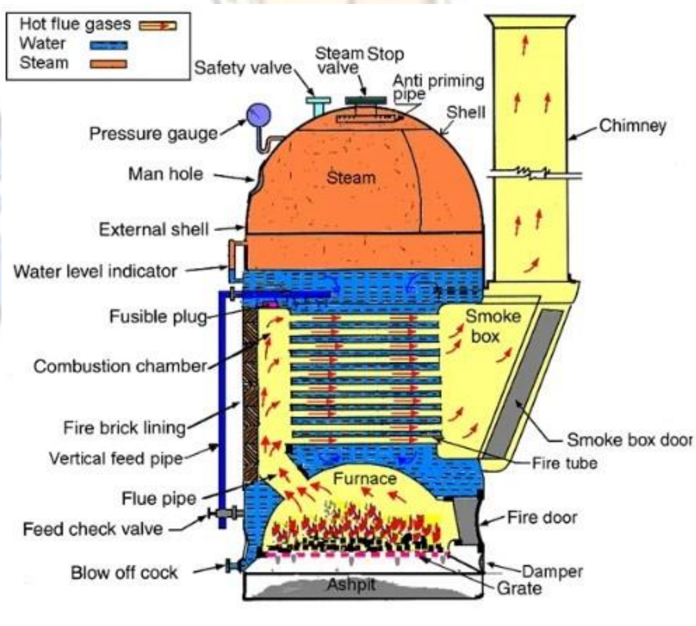
## Blow-Off Valve:

To maintain boiler efficiency, a blow-off valve is employed to periodically remove impurities like mud, sand, and salt, which accumulate in the water during heating and could cause operational issues.

## Working Principle:

The Cochran boiler operates in a manner akin to other fire tube boilers, as elucidated by the following steps:

- Coal is introduced onto the grate via a fire hole.
- Air from the surroundings enters the combustion chamber.
- Fuel is ignited through the fire hole.
- The resulting combustion gases flow into the hemisphere-shaped partition chamber.
- These flue gases continue through the fire tubes.
- Heat is transferred from the gases to the water within the fire tubes.
- Steam accumulates in the upper section of the shell, and once the desired pressure is attained, it is extracted.
- The flue gases subsequently exit through a firebox and are released into the atmosphere.




## Advantages:

- Compact and space-efficient design.
- Efficient heat transfer due to multiple fire tubes.
- Versatile fuel options, including solid fuels like coal.
- Suitable for both small-scale and industrial applications.

- Quick steam generation and easy control of pressure.
- Robust construction for long-term durability.
- Minimal maintenance requirements.
- Cost-effective and energy-efficient.

**Disadvantages:**

- Limited steam generation capacity compared to larger boilers.
- Requires skilled personnel for efficient operation.
- Not suitable for high-pressure applications.
- Potential for inefficient fuel combustion if not properly maintained.
- Prone to scale buildup in the fire tubes if water quality is poor.
- Initial installation costs can be relatively high.

**Applications:**

- Industrial processes requiring steam, such as textile and chemical manufacturing.
- Heating systems for commercial and residential buildings.
- Steam-driven power generation in small-scale plants.
- Educational and research purposes for boiler training.
- Steam locomotives and marine propulsion systems.
- Food processing facilities, including breweries and distilleries.
- Hospitals and healthcare facilities for sterilization and heating.

## Working principle of locomotive boiler:

Locomotive Boiler: Locomotive boiler is the type of horizontal fire tube boiler it has multi-tubular combustion takes place ingrate by the supply of coal into Locomotive Boiler. Locomotive Boiler is also called as fire tube boiler. Locomotive Boiler is used to create steam from water by using heat energy.

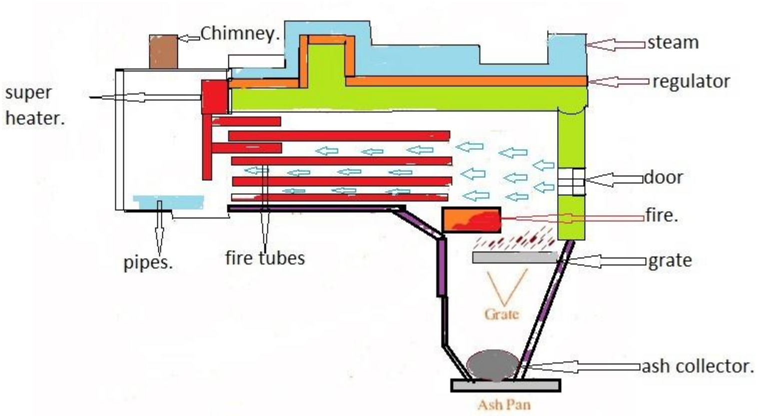
### Main parts of Locomotive Boiler:

Locomotive Boiler has Different Parts they are as follows:

- Firebox
- Cylindrical shell
- Smoke box
- Chimney
- Grate
- Ash pan
- Super heater tubes

- Valves

- Damper




## Working Principle:

The locomotive boiler is the type of horizontal fire tube boiler it has multi-tubular combustion takes place ingrate by the supply of coal into it, Hot flue gases deflects by the fire bridge this flow into the fire tubes. by this fire tubes, the hot gases are used to flow through the cylindrical shell and enter into horizontal tubes in it.

In this, the water is heated by hot gases and formed into saturated steam this steam collects at the top of the shell. this saturated steam gets into the steam pipe and goes into super heater header by this steam gets super heated, this super heated steam used to supply to the engine. the gases in the tubes are discharged into the atmosphere by the help of chimney after passing through the smoke box.

The steam capacity is about 9000kg/hr, and efficiency is about 70%, working pressure is about 14bar.

## Advantages:

1. It is portable.
2. This boiler is capable of meeting sudden and fluctuating demands of steam.
3. It is a cost-effective boiler.
4. High steam generation rate.
5. It is compact in size and its operation is easy.

## Disadvantages:

1. It faces the problems of corrosion and scale formation.
2. Unable to work under heavy load conditions because of overheating problems.
3. Some of its water space is difficult to clean.
4. The overall efficiency is less.

**Application:**

1. Locomotive boilers are used in railways and marines.
2. This type of boiler is used in traction engines.
3. This is also used in steam rollers.
4. It is can be used in portable steam engines and some other steam road vehicles.

## Boiler Fittings or Mountings:

The necessary devices installed or mounted for the safety of the boiler and its control are called boiler mountings. The boiler fittings or mountings are devices that are attached to the boiler to ensure correct operation. Mountings include a pressure gauge, safety valve, steam stop valve, blow-off valve or blow down valve and feed check valve.

### Water Level Indicator

A water level indicator is a glass tube with a water level indicator installed outside the boiler shell that shows the water level inside the boiler. Water should continue to be present in the boiler at the pre-determined level. If the water falls below the level due to the change of phase into steam and simultaneously fresh water does not fill in for some reason, the hot surface may expose to steam only and overheat. This is because steam has a very low heat transfer coefficient compared to water.

### Pressure Gauge

A pressure gauge is used to indicate the pressure of steam in the boiler. It is generally mounted on the front top of the boiler. The pressure gauge is of two types as (i) Bourdon Tube Pressure Gauge (ii) Diaphragm type pressure gauge. Both of these gauges have a dial on which, when pressure is applied, a needle travels over a circular scale. It displays a measurement of zero at atmospheric pressure.

### Safety Valves

In order to protect the boiler from excessive pressure, a spring-loaded safety valve with a secure mounting must be installed on the boiler shell. It is an essential component of the boiler and must always be functioning properly to prevent the boiler from exploding under high pressure and thereby saving lives and property.

### Steam Stop Valve

Steam Stop Valve is installed over the boiler between the steam space and the steam supply pipe. The job of the steam stop valve is to control how much steam is supplied from the boiler to the steam pipe.

### Blow-off Valve or Blow Down Valve

It is a controllable valve opening at the bottom of the boiler's water area that is used to drain some water from the bottom that contains mud or other sediments that have accumulated while the boiler has been operating. Additionally, when the boiler is turned off for cleaning or for inspection and repair, it is used to fully empty the water.

### Feed Check Valve

After the feed pump, the feed check valve is installed in the boiler's feed water pipe. Its purpose is to prevent backflow when the feed pump pressure is less than the boiler pressure and to enable water to flow into the boiler when the discharge pressure of the feed pump is greater than the inside steam pressure of the boiler.

### Fusible Plug

Fusible plugs are used to prevent boiler harm from boiler tube overheating caused by low water levels.

## Boiler Accessories:

The devices which are installed in the boiler for their efficient operation and smooth working are called Boiler Accessories. A superheater, an economiser, a feed compressor, etc. are some of them. It should be mentioned that the accessories aid in effectively controlling and operating the boiler.

### Economizer

An economizer is a heat exchanger that has been specifically designed to capture the thermal energy of exhaust flue gases and use it to pre-heat boiler feed water. By improving the boiler's thermal efficiency, it conserves heat energy and thereby fuel and lowers the running costs of the boiler.

### Air Preheater

The purpose of an air preheater is to further utilise the heat contained in flue fumes after they exit an economizer by preheating air for use in an oil burner or furnace.

### Superheater

The purpose of a superheater is to raise vapour temperature above its saturation point. This kind of thermal exchanger does that. The superheater comes first before the boiler when hot flue fumes exit the burner. The primary benefit of superheating steam is that it can be used in power plants to expand steam through a turbine.

### Feed Pump

A feed pump is located close to the furnace and is used to supply the high-pressure boiler with water. The function of the feed pump is not simply to supply water to the boiler. Rather, because the boiler operates at high pressure, the feed pump's discharge pressure must be considerably higher than this to force water into the boiler.

**Difference between Mountings and Accessories**

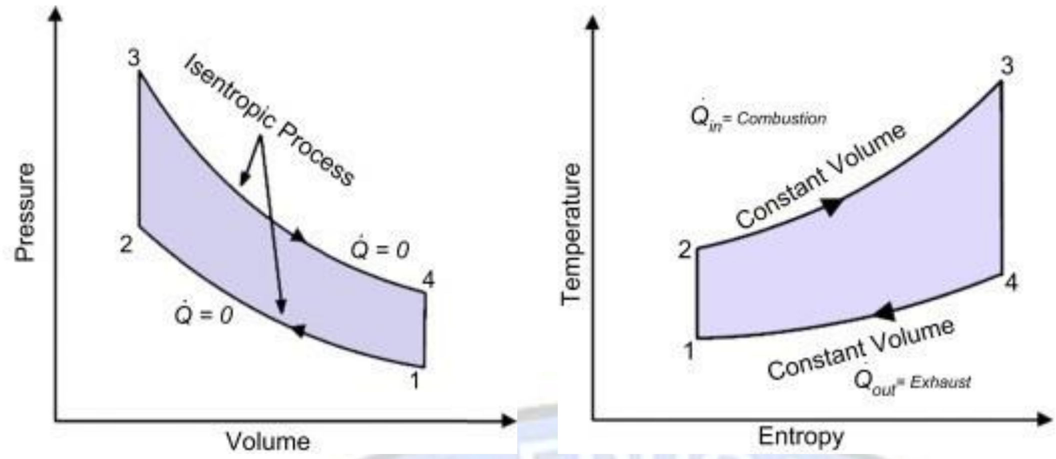
| Boiler Mountings | Boiler Accessories |
|---|---|
| Boiler Mountings are there for the safety of a boiler | Boiler Accessories are there for the efficiency of a boiler |
| Boiler Mountings are necessary for the working of the boiler. | Boiler Accessories are not necessary but their use is recommended for the working of the boiler. |
| Boiler Mountings are mounted on boiler shells. | Boiler Accessories are not mounted on the boiler shell. |
| Boiler Mountings are installed from simple working and control of a boiler. | Boiler Accessories are installed to amplify the efficiency of a boiler. |
| eg. Water level, indicator, Pressure gauge. | eg. : Superheater, Economiser. |

## Constant Volume or Otto Cycle:

This is a constant volume cycle on which petrol and gas engines will work. Heat addition and rejection takes place at constant volume that is why it is called as Constant volume cycle.

The cycle, illustrated shown above figure consists the following sequence of operations.

**Process 1-2: Adiabatic Compression**: In this process air is compressed inside the cylinder, thus raising the pressure and temperature of the air. No heat transfer takes place and entropy is constant.




**P-V & T-S diagrams of Otto cycle**

**Process 2-3: Constant Volume process**: In this process heat addition takes place and volume remains constant. Here work done is zero. But pressure and temperature of the air increases further maximum value attained in the cycle. Entropy increase.

**Process 3-4**: **Adiabatic Expansion**: During expansion process pressure and temperature decrease. Entropy is constant that is no heat transfer takes place.

**Process 4-1:** Constant Volume Process: Here heat rejection takes place. During this process entropy decrease, pressure and temperature also decrease to initial state. Thus cycle is completed.

Consider **1 kg of air** (working substance) :

Heat supplied at constant volume $= c_v(T_3 - T_2)$.

Heat rejected at constant volume $= c_v\,(T_4 - T_1)$.

But, work done = Heat supplied – Heat rejected

$$= c_v\,(T_3 - T_2) - c_v\,(T_4 - T_1)$$

$$\therefore \quad \text{Efficiency} = \frac{\text{Work done}}{\text{Heat supplied}} = \frac{c_v\,(T_3 - T_2) - c_v\,(T_4 - T_1)}{c_v\,(T_3 - T_2)}$$

$$= 1 - \frac{T_4 - T_1}{T_3 - T_2} \qquad \ldots(i)$$

Let compression ratio, $r_c\ (= r) = \dfrac{v_1}{v_2}$

and expansion ratio, $r_e\ (= r) = \dfrac{v_4}{v_3}$

(These *two ratios are same* in this cycle)

As $\quad \dfrac{T_2}{T_1} = \left(\dfrac{v_1}{v_2}\right)^{\gamma - 1}$

Then, $\quad T_2 = T_1 \,.\, (r)^{\gamma - 1}$

Similarly, $\quad \dfrac{T_3}{T_4} = \left(\dfrac{v_4}{v_3}\right)^{\gamma - 1}$

or $$T_3 = T_4 \cdot (r)^{\gamma-1}$$

Inserting the values of $T_2$ and $T_3$ in equation (*i*), we get

$$\eta_{otto} = 1 - \frac{T_4 - T_1}{T_4 \cdot (r)^{\gamma-1} - T_1 \cdot (r)^{\gamma-1}} = 1 - \frac{T_4 - T_1}{r^{\gamma-1}(T_4 - T_1)}$$

$$= 1 - \frac{1}{(r)^{\gamma-1}}$$

The above expression is known as the **air standard efficiency of the Otto cycle**. It is clear from the above expression that efficiency increases with the increase in the value of r, which means we can have maximum efficiency by increasing r to a considerable extent, but due to practical difficulties its value is limited to about 8.

## Constant Pressure or Diesel Cycle:

This cycle was introduced by Dr. R. Diesel in 1897. It differs from Otto cycle in that heat is supplied at constant pressure instead of at constant volume. Fig. (a and b) shows the p-v and T-s diagrams of this cycle respectively.

This cycle comprises of the following operations:

(i) 1-2 Adiabatic compression.

(ii) 2-3 Addition of heat at constant pressure.

(iii) 3-4 Adiabatic expansion.

(iv) 4-1 Rejection of heat at constant volume.

Point 1 represents that the cylinder is full of air. Let $p_1$, $V_1$ and $T_1$ be the corresponding pressure, volume and absolute temperature. The piston then compresses the air adiabatically (i.e., $pV^\gamma$ = constant) till the values become $p_2$, $V_2$ and $T_2$ respectively (at the end of the stroke) at point 2. Heat is then added from a hot body at a constant pressure. During this addition of heat let volume increases from $V_2$ to $V_3$ and temperature $T_2$ to $T_3$, corresponding to point 3. This point (3) is called the **point of cut-off**. The air then expands adiabatically to the conditions $p_4$, $V_4$ and $T_4$ respectively corresponding to point 4. Finally, the air rejects the heat to the cold body at constant volume till the point 1 where it returns to its original state.

*Consider 1 kg of air.*

Heat supplied at constant pressure $= c_p(T_3 - T_2)$

Heat rejected at constant volume $= c_v(T_4 - T_1)$

Work done = Heat supplied – heat rejected

$$= c_p(T_3 - T_2) - c_v(T_4 - T_1)$$

$$\therefore \quad \eta_{diesel} = \frac{\text{Work done}}{\text{Heat supplied}}$$

$$= \frac{c_p(T_3 - T_2) - c_v(T_4 - T_1)}{c_p(T_3 - T_2)}$$

$$= 1 - \frac{(T_4 - T_1)}{\gamma(T_3 - T_2)} \quad \ldots(i) \quad \left[\because \frac{c_p}{c_v} = \gamma\right]$$

Let compression ratio, $r = \frac{v_1}{v_2}$, and cut-off ratio, $\rho = \frac{v_3}{v_2}$ *i.e.,* $\frac{\text{Volume at cut-off}}{\text{Clearance volume}}$

Now, during *adiabatic compression 1-2,*

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma - 1} = (r)^{\gamma - 1} \quad \text{or} \quad T_2 = T_1 \, . \, (r)^{\gamma - 1}$$

During *constant pressure process 2-3,*

$$\frac{T_3}{T_2} = \frac{v_3}{v_2} = \rho \quad \text{or} \quad T_3 = \rho \, . \, T_2 = \rho \, . \, T_1 \, . \, (r)^{\gamma - 1}$$

During *adiabatic expansion 3-4*

$$\frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right)^{\gamma - 1}$$

$$= \left(\frac{r}{\rho}\right)^{\gamma - 1} \quad \left(\because \frac{v_4}{v_3} = \frac{v_1}{v_3} = \frac{v_1}{v_2} \times \frac{v_2}{v_3} = \frac{r}{\rho}\right)$$

$$\therefore \quad T_4 = \frac{T_3}{\left(\frac{r}{\rho}\right)^{\gamma - 1}} = \frac{\rho \, . \, T_1 (r)^{\gamma - 1}}{\left(\frac{r}{\rho}\right)^{\gamma - 1}} = T_1 \, . \, \rho^{\gamma}$$

By inserting values of $T_2$, $T_3$ and $T_4$ in eqn. ($i$), we get

$$\eta_{diesel} = 1 - \frac{(T_1 \, . \, \rho^{\gamma} - T_1)}{\gamma \, (\rho \, . \, T_1 \, . \, (r)^{\gamma - 1} - T_1 \, . \, (r)^{\gamma - 1})} = 1 - \frac{(\rho^{\gamma} - 1)}{\gamma (r)^{\gamma - 1} (\rho - 1)}$$

or

$$\eta_{diesel} = 1 - \frac{1}{\gamma (r)^{\gamma - 1}} \left[\frac{\rho^{\gamma} - 1}{\rho - 1}\right]$$

It may be observed that above eqn. for efficiency of diesel cycle is different from that of the Otto cycle only in bracketed factor. This factor is always greater than unity, because $\rho > 1$. Hence for a given compression ratio, the Otto cycle is more efficient

**Difference between Otto cycle and Diesel cycle**

| Sl No. | Otto Cycle | Diesel Cycle |
|---|---|---|
| 1. | Otto cycle has low thermal efficiency. | The diesel cycle has high thermal efficiency. |
| 2. | It has a low compression ratio. | But This one works on a high |

| | | |
|---|---|---|
| | | compression ratio. |
| 3. | Otto cycle is also called a Constant volume cycle. | The diesel cycle is called a constant pressure cycle. |
| 4. | Otto cycle system is light in weight. But | The diesel cycle is heavy in weight. |
| 5. | explosion process takes place at constant volume process and | In the diesel engine, the explosion The process takes place at a constant pressure process. |
| 6. | The Spark Plug is used here for igniting the charge. | A fuel injector is used here for igniting the charge. |
| 7. | A mixture of air and fuel is entered in suction stroke. | Only air is entered in suction stroke. |
| 8. | Here the working fuel is used as Petrol. | The working fuel is used as Diesel. |
| 9. | Otto cycle engine is the high-speed engines. | Diesel cycle engines are not high-speed engine comparatively Otto cycle. |
| 10. | The engine starting is easy in cold weather too. | But here it is difficult comparatively Otto cycle |

## Refrigeration and Air Conditioning Cycles:

**Refrigeration** is the science of producing and maintaining temperatures below that of the surrounding atmosphere. This means the removing of heat from a substance to be cooled. Heat always passes downhill, from a warm body to a cooler one, until both bodies are at the same temperature.

In simple, refrigeration means the cooling of or removal of heat from a system. The equipment employed to maintain the system at a low temperature is termed as refrigerating system and the system which is kept at lower temperature is called refrigerated system. Refrigeration is generally produced in one of the following three ways:

(i) By melting of a solid.

(ii) By sublimation of a solid.

(iii) By evaporation of a liquid.

Most of the commercial refrigeration is produced by the evaporation of a liquid called refrigerant. Mechanical refrigeration depends upon the evaporation of liquid refrigerant and its circuit includes the equipments naming **evaporator, compressor, condenser** and **expansion valve**. It is used for preservation of food, manufacture of ice, solid carbon dioxide and control of air temperature and humidity in the air-conditioning system.

## Important refrigeration applications:

1. Ice making
2. Transportation of foods above and below freezing
3. Industrial air-conditioning
4. Comfort air-conditioning
5. Chemical and related industries
6. Medical and surgical aids
7. Processing food products and beverages
8. Oil refining and synthetic rubber manufacturing
9. Manufacturing and treatment of metals
10. Freezing food products.

## Elements of Refrigeration Systems:

All refrigeration systems must include at least four basic units as given below:

*(i) A low temperature thermal "sink" to which heat will flow from the space to be cooled.*

*(ii) Means of extracting energy from the sink, raising the temperature level of this energy, and delivering it to a heat receiver.*

*(iii) A receiver to which heat will be transferred from the high temperature high- pressure refrigerant.*

*(iv) Means of reducing of pressure and temperature of the refrigerant as it returns from the receiver to the "sink".*

## Refrigeration Systems:

The various refrigeration systems may be enumerated as below:

1. Ice refrigeration 2. Air refrigeration system 3. Vapour compression refrigeration system 4. Vapour absorption refrigeration system

## Co-efficient of Performance (C.O.P.)

The performance of a refrigeration system is expressed by a term known as the ''co-efficient of performance'', which is defined as the ratio of heat absorbed by the refrigerant while passing through the evaporator to the work input required to compress the refrigerant in the compressor; in short it is the ratio between heat extracted and work done (in heat units).

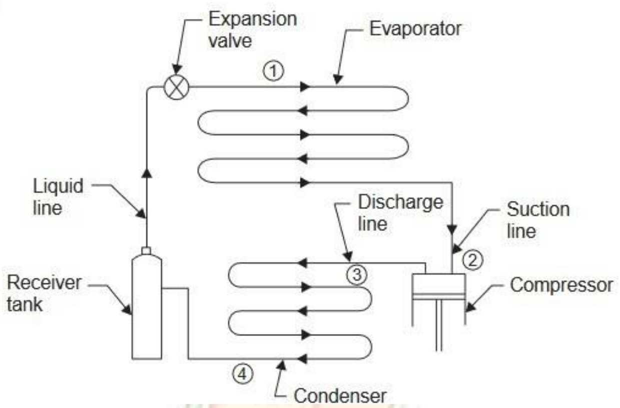
## Simple Vapour Compression System:

Out of all refrigeration systems, the vapour compression system is the most important system from the view point of commercial and domestic utility. It is the most practical form of refrigeration. In this system the working fluid is a vapour. It readily evaporates and condenses or changes alternately between the vapour and liquid phases without leaving the refrigerating plant. During evaporation, it absorbs heat from the cold body

In a simple vapour compression system fundamental processes are completed in one cycle.

These are :

1. Compression 2. Condensation 3. Expansion 4. Vapourisation




**Vapour compression system**

The vapour at low temperature and pressure (state '2') enters the "compressor" where it is compressed isentropically and subsequently its temperature and pressure increase considerably (state '3'). This vapour after leaving the compressor enters the ''condenser" where it is condensed into high pressure liquid (state '4') and is collected in a "receiver tank". From receiver tank it passes through the "expansion valve", here it is throttled down to a lower pressure and has a low temperature (state '1'). After finding its way through expansion "valve" it finally passes on to "evaporator" where it extracts heat from the surroundings or circulating fluid being refrigerated and vapourises to low pressure vapour (state '2').

### Functions of Parts of a Simple Vapour Compression System:

Here follows the brief description of various parts of a simple vapour compression system shown in above fig.

1. **Compressor.** The function of a compressor is to remove the vapour from the evaporator, and to raise its temperature and pressure to a point such that it (vapour) can be condensed with available condensing media.

2. **Discharge line** (or hot gas line). A hot gas or discharge line delivers the high-pressure, high-temperature vapour from the discharge of the compressor to the condenser.

3. **Condenser.** The function of a condenser is to provide a heat transfer surface through which heat passes from the hot refrigerant vapour to the condensing medium.

4. **Receiver tank.** A receiver tank is used to provide storage for a condensed liquid so that a constant supply of liquid is available to the evaporator as required.

5. **Liquid line.** A liquid line carries the liquid refrigerant from the receiver tank to the refrigerant flow control.

6. **Expansion valve** (refrigerant flow control). Its function is to meter the proper amount of refrigerant to the evaporator and to reduce the pressure of liquid entering the evaporator so that liquid will vapourize in the evaporator at the desired low temperature and take out sufficient amount of heat.

7. **Evaporator.** An evaporator provides a heat transfer surface through which heat can pass from the refrigerated space into the vapourizing refrigerant.

8. **Suction line.** The suction line conveys the low pressure vapour from the evaporator to the suction inlet of the compressor.

## Refrigerants:

A ‘refrigerant’ is defined as any substance that absorbs heat through expansion or vaporisation and loses it through condensation in a refrigeration system. The term ‘refrigerant’ in the broadest sense is also applied to such secondary cooling mediums as cold water or brine, solutions. Usually refrigerants include only those working mediums which pass through the cycle of evaporation, recovery, compression, condensation and liquification. These substances absorb heat at one place at low temperature level and reject the same at some other place having higher temperature and pressure. The rejection of heat takes place at the cost of some mechanical work.

## Desirable properties of an ideal refrigerant:

As a rule the selection of a refrigerant is a compromise between the conflicting desirable properties, for example, evaporator pressure should be as high as possible and at the same time the condenser pressure should be as low as possible. Both of these requirements are difficult to satisfy. Low viscosity and low surface tension are desirable but these make it difficult to provide drop-wise condensation that improves the heat transfer during condensation. Easy availability is also one of the criteria. In general, the desirable properties of refrigerants are:

1. **Thermodynamic properties:**

(i) Low boiling point

(ii) Low freezing point

(iii) Positive pressures (but not very high) in condenser and evaporator.

2. **Chemical Properties:**

(i) Non-toxicity

(ii) Non-flammable and non-explosive

(iii) Non-corrosiveness

(iv) No effect on the quality of stored (food and other) products like flowers, with other materials i.e., furs and fabrics.

3. **Physical Properties:**

(i) Low specific volume of vapour

(ii) Low specific heat

(iii) High thermal conductivity

(iv) Low viscosity

(v) High electrical insulation.

4. **Other Properties:**

(i) Ease of leakage location

(ii) Availability and low cost

(iii) Ease of handling

(iv) High C.O.P.

(v) Low power consumption per tonne of refrigeration.

(vi) Low pressure ratio and pressure difference.

## Properties and Uses of Commonly Used Refrigerants:

1. **Air**

**Properties:**

(i) No cost involved; easily available.

(ii) Completely non-toxic.

(iii) Completely safe.

(iv) The C.O.P. of air cycle operating between temperatures of 80°C and – 15°C is 1.67.

**Uses:**

(i) Air is one of the earliest refrigerants and was widely used even as late as World War I wherever a completely non-toxic medium was needed.

(ii) Because of low C.O.P., it is used only where operating efficiency is secondary as in air-craft refrigeration.

**2. Ammonia**

**($NH_3$)**

**Properties:**

(i) It is highly toxic and flammable.

(ii) It has the excellent thermal properties.

(iii) It has the highest refrigerating effect per kg of refrigerant.

(iv) High efficiency.

(v) Low cost.

(vi) Low weight of liquid circulated per tonne of refrigeration.

**Uses:**

(i) It is widely used in large industrial and commercial reciprocating compression systems where high toxicity is secondary.

It is extensively used in ice plants, packing plants, large cold storages and skating rinks etc.

(ii) It is widely used as the refrigerant in absorption systems. The following points are worth noting:

• Ammonia should never be used with copper, brass and other copper alloys ; iron and steel should be used in ammonia systems instead.

• In ammonia systems, to detect the leakage a sulphur candle is used which gives off a dense white smoke when ammonia vapour is present.

**3. Sulphur dioxide**

**($SO_2$) Properties:**

(i) It is a colourless gas or liquid.

(ii) It is extremely toxic and has a pungent irritating odour.

(iii) It is non-explosive and non-flammable.

(iv) It has a liquid specific gravity of 1.36.

(v) Works at low pressures.

(vi) Possesses small latent heat of vapourisation.

**Uses:**

It finds little use these days. However its use was made in small machines in early days.

- The leakage of sulphur dioxide may be detected by bringing aqueous ammonia near the leak, this gives off a white smoke.

### 4. Carbon dioxide

### ($CO_2$) Properties:

(i) It is a colourless and odourless gas, and is heavier than air.

(ii) It has liquid specific gravity of 1.56.

(iii) It is non-toxic and non-flammable.

(iv) It is non-explosive and non-corrosive.

(v) It has extremely high operating pressures.

(vi) It gives very low refrigerating effect.

**Uses:**

This refrigerant has received only limited use because of the high power requirements per tonne of refrigeration and the high operating pressures. In former years it was selected for marine refrigeration, for theater air- conditioning systems, and for hotel and institutional refrigeration instead of ammonia because it is non-toxic.

At the present-time its use is limited primarily to the manufacture of dry ice (solid carbon dioxide).

- The leak detection of CO 2 is done by soap solution.

### 5. Methyl Chloride ($CH_3$

### Cl) Properties:

(i) It is a colourless liquid with a faint, sweet, non-irritating odour.

(ii) It has liquid specific gravity of 1.002 at atmospheric pressure.

(iii) It is neither flammable nor toxic.

**Uses:**

It has been used in the past in both domestic and commercial applications. It should never be used with aluminium.

### 6. R-11 (Trichloro monofluoro methane)

**Properties:**

(i) It is composed of one carbon, three chlorine and one fluorine atoms (or parts by weight)

and is non-corrosive, non-toxic and non-flammable.

(ii) It dissolves natural rubber.

(iii) It has a boiling point of – 24°C.

(iv) It mixes completely with mineral lubricating oil under all conditions.

**Uses:**

It is employed for 50 tonnes capacity and over in small office buildings and factories. A centrifugal compressor is used in the plants employing this refrigerant.

- Its leakage is detected by a halide torch.

**R-12 (Dichloro-difluoro methane) or Freon-12 Properties:**

(i) It is non-toxic, non-flammable, and non-explosive, therefore it is most suitable refrigerant.

(ii) It is fully oil miscible therefore it simplifies the problem of oil return.

(iii) The operating pressures of R-12 in evaporator and condenser under standard tonne of refrigeration are 1.9 bar abs. and 7.6 bar abs. (app.).

(iv) It s latent heat at – 15°C is 161.6 kJ/kg.

(v) C.O.P. = 4.61.

(vi) It does not break even under the extreme operating conditions.

(vii) It condenses at moderate pressure and under atmospheric conditions.

**Uses:**

1. It is suitable for high, medium and low temperature applications.
2. It is used for domestic applications.
3. It is excellent electric insulator therefore it is universally used in sealed type compressors.

**8. R-22 (Monochloro-difluoro methane) or Freon-22**

R-22 refrigerant is superior to R-12 in many respects. It has the following properties and uses:

**Properties:**

(i) The compressor displacement per tonne of refrigeration with R-22 is 60% less than the compressor displacement with R-12 as refrigerant.

(ii) R-22 is miscible with oil at condenser temperature but tries to separate at evaporator temperature when the system is used for very low temperature applications (– 90°C). Oil separators must be incorporated to return the oil from the evaporator when the system is used for such low temperature applications.

(iii) The pressures in the evaporator and condenser at standard tonne of refrigeration are 2.9 bar abs. and 11.9 bar abs. (app.).

(iv) The latent heat at – 15°C is low and is 89 kJ/kg.

The major disadvantage of R-22 compared with R-12 is the high discharge temperature which requires water cooling of the compressor head and cylinder.

**Uses:**

R-22 is universally used in commercial and industrial low temperature systems.

**Classification of Refrigerants**

The refrigerants are classified as follows:

1. Primary refrigerants.
2. Secondary refrigerants.

1. **Primary refrigerants** are those working mediums or heat carriers which directly take part in the refrigeration system and cool the substance by the absorption of latent heat e.g. Ammonia, Carbon dioxide, Sulphur dioxide, Methyl chloride, Methylene chloride, Ethyl chloride and Freon group etc.

2. **Secondary refrigerants** are those circulating substances which are first cooled with the help of the primary refrigerants and are then employed for cooling purposes, e.g. ice, solid carbon dioxide etc. These refrigerants cool substances by absorption of their sensible heat.

The primary refrigerants are grouped as follows:

**(i) Halocarbon compounds.** In this group are included refrigerants which contain one or more of three halogens, chlorine and bromine and they are sold in the market under the names as Freon, Genetron, Isotron, and Areton. Since the refrigerants belonging to this group have outstanding merits over the other group's refrigerants, therefore they find wide field of application in domestic, commercial and industrial purposes.

The list of the halocarbon-refrigerants commonly used is given below :

R-10 — Carbon tetrachloride ($CCl_4$)

R-11 — Trichloro-monofluoro methane ($CCl_3F$)

R-12 — Dichloro-difluoro methane ($CCl_2F_2$)

R-13 — Mono-bromotrifluoro methane ($CBrF_3$)

R-21 — Dichloro monofluoro methane ($CHCl_2F$)

R-22 — Mono chloro difluoro methane ($CHClF_2$)

R-30 — Methylene-chloride ($CH_2Cl_2$)

R-40 — Methyle chloride ($CH_3Cl$)

R-41 — Methyle fluoride ($CH_3F$)

R-100— Ethyl chloride ($C_2H_5Cl$)

R-113— Trichloro trifluoroethane ($C_2F_3Cl_3$)

R-114— Tetra-fluoro dichloroethane ($Cl_2F_4Cl_2$)

R-152— Difluoro-ethane ($C_2H_6F_2$)

**(ii) Azeotropes.** The refrigerants belonging to this group consists of mixtures of different substances. These substances cannot be separated into components by distillations. They possess fixed thermodynamic properties and do not undergo any separation with changes in temperature and pressure. An azeotrope behaves like a simple substance.

Example. R-500. It contains 73.8% of (R-12) and 26.2% of (R-152).

**(iii) Hydrocarbons.** Most of the refrigerants of this group are organic compounds. Several hydrocarbons are used successfully in commercial and industrial installations. Most of them possess satisfactory thermodynamic properties but are highly inflammable. Some of the important refrigerants of this group are:

R-50 — Methane ($CH_4$)

R-170— Ethane ($C_2H_6$)

R-290— Propane ($C_2H_8$)

R-600— Butane ($C_4H_{10}$)

R-601— Isobentane [$CH(CH_3)_3$]

**(iv) Inorganic compounds.** Before the introduction of hydrocarbon group these refrigerants were most commonly used for all purposes.

The important refrigerants of this group are:

R-717 — Ammonia ($NH_3$)
R-718 — Water ($H_2O$)
R-729 — Air (mixture of $O_2$, $N_2$, $CO_2$ etc.)
R-744 — Carbon dioxide ($CO_2$)
R-764 — Sulphur dioxide ($SO_2$)

## Basic Principles of Air Conditioning:

Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favorable 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 **Equipments used in an Air Conditioning System:**

1. *Circulation fan.* The main function of this fan is to move air to and from the room.
2. *Air conditioning unit.* It is a unit which consists of cooling and dehumidifying processes for summer air conditioning or heating and humidification processes for winter air conditioning.
3. *Supply duct.* It directs the conditioned air from the circulating fan to the space to be air conditioned at proper point.
4. *Supply outlets.* These are grills which distribute the conditioned air evenly in the room.
5. *Return outlets.* These are the openings in a room surface which allow the room air to enter the return duct.
6. *Filters.* The main function of the filters is to remove dust, dirt and other harmful bacteria from the air.

**Classification of Air Conditioning Systems:**

**The air conditioning system may be broadly classified as follows:**

**a. According to the purpose**

(i) Comfort air conditioning system.

(ii) Industrial air conditioning system.

**b. According to a season of the year**

(i) Winter air conditioning system.

(ii) Summer air conditioning system.

(iii) Year-round air conditioning system.

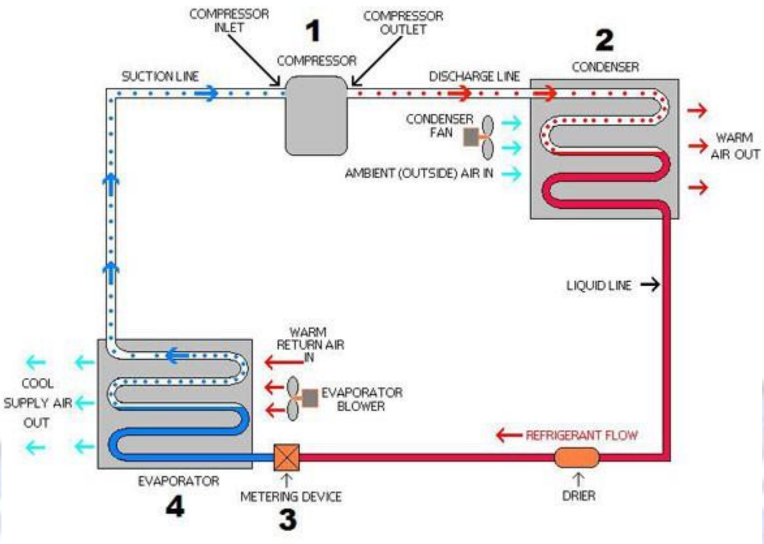
**c. According to the arrangement of equipment**

(i) The unitary air conditioning system

(ii) Central air conditioning system.

## Room Air Conditioner:

It is also called window air conditioner because it is normally fixed in a window or wall opening. It works on the principle of vapour compression refrigeration system. The refrigerant $_{3}c_{5}$ommonly used R-12, R-22.It consists of condenser, compressor, evaporator, fan (blower) and filter. Compressor and condenser are projected outside the room and evaporator projected inside the room.

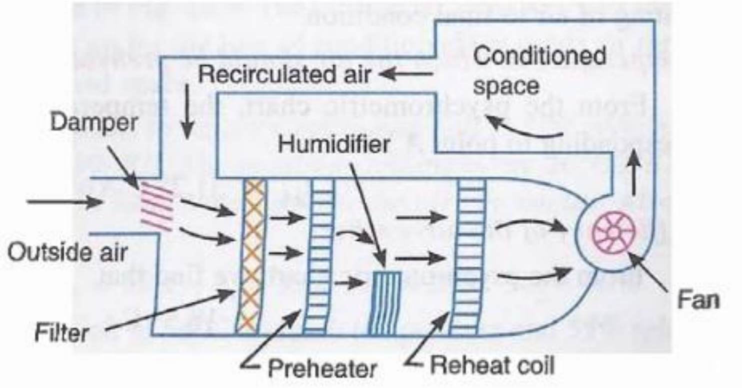



**Schematic diagram of room air conditioner**

**Working Principle:** The refrigerant vapour leaving the compressor is at high pressure and temperature. It enters the condenser. Outside air is drawn in by the can and it cools the refrigerant (phase change i.e., liquid) in the condenser. The high pressure, low temperature liquid refrigerant stored in vessel known as receiver. It supplies the liquid refrigerant stored in vessel known as receiver. It supplies the liquid refrigerant to evaporator through expansion valve. The function of expansion valve is to reduces high pressure liquid to low pressure liquid and temperature also. The cold refrigerant from the valve passes through evaporator. The warm air from the room is drawn in by blower. The evaporator cools this air and liquid refrigerant inside the evaporator to be gets vaporized by absorbing the heat from the warm air. The cool air is again sent to the room inside through the evaporator. Here refrigerant change its state (i.e.,vapour) refrigerant enters through the compressor cycle is repeated.

## Winter Air Conditioning System:

In winter air conditioning system, the air is burnt and heated, which is generally followed by humidification (Heating and humidification).

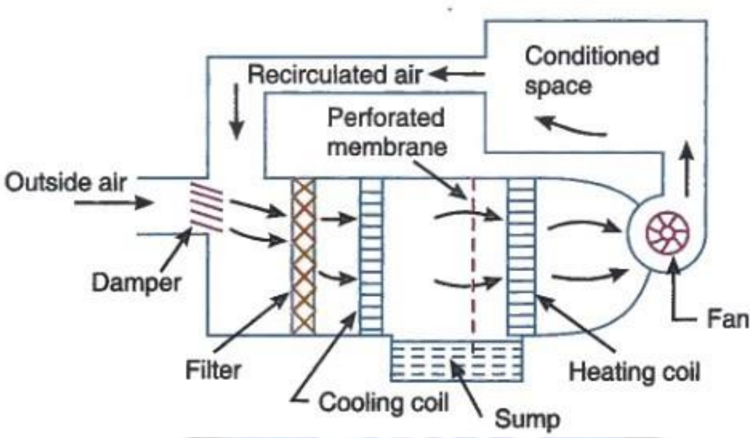



**Winter Air Conditioning System**

The outside air flows through a damper and mixes with the recirculated air. The mixed air passes through a filter to remove the dirt, dust and impurities. The air now passes through a preheat coil to prevent the possible freezing of water and to control the evaporation of water in the humidities. After that, the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature. Now, the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the air is exhausted to the atmosphere by the exhaust fans. The remaining part of the used air is again conditioned and this will repeat again and again.

## Summer Air Conditioning System:

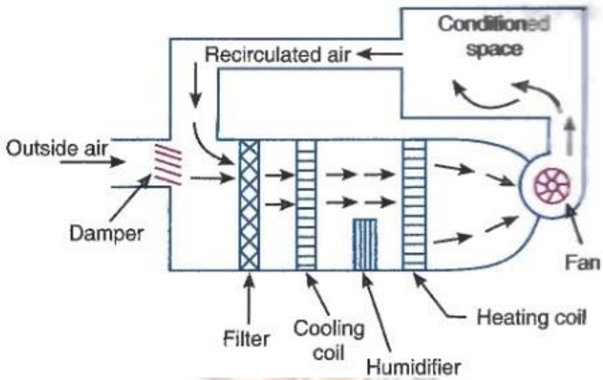
In summer air conditioning system, the air is cooled and generally dehumidified (Cooling and dehumidifying). Schematic for a typical summer air conditioning system is arranged. The outside air flows through the damper and mixed with recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove the dirt, dust and impurities. The air now passes through a cooling coil. The coil has a temperature much below the required dry bulb temperature of the air in the conditioned space. The cooled air passes through a perforated membrane and loses its moisture in the condensed from which is collected in the sump. After that, the air is made to pass through a heating coil which heats the air slowly. This is done to bring the air to the designed dry bulb temperature and relative humidity. Now the conditioned air is supplied to the conditioned space by a fan. From conditioned space, a part of the used air is rejected to the atmosphere by the exhaust fan. The remaining air is again conditioned and this repeated for again and again.




**Summer Air Conditioning System**

## Year-Round Air Conditioning System:

In year-round air conditioning system, it should have equipment for both the summer and winter air conditioning. In this, the outside air flows through the damper and mixed with the recirculated air. The mixed air passes through a filter to remove dirt, dust and impurities.




**Year-Round Air Conditioning System**

In summer air conditioning system, the cooling by operates to cool the air to the desired valve. The dehumidification is obtained by operating the cooling coil at a lower temperature than the dew point temperature.

In winter air conditioning system, the cooling coil is made inoperative and the heating coil operates to heat the air. The spray type humidifier is also used in the dry season to humidify the air.

## Application of Air-Conditioning:

- ➢ Using air-conditioner is common in food cooking and processing areas. Used in hospital operating theatres to provide comfortable conditions to patients. And many more industries like Textile, Printing, Photographic and much more.
- ➢ Air-conditioning system used as the commercial purpose for a human being. Example, in Theatres, Departmental store-room etc.

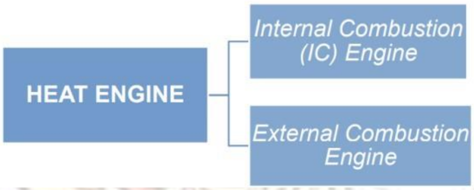
- ➢ Many of transport vehicles use air-conditioning systems such as cars, trains, aircraft, ships etc. This provides a comfortable condition for the passengers.
- ➢ The air-conditioning system used in Television-centres, Computer centres and museum for a special purpose.

**HEAT ENGINE:**

Any engine that converts thermal energy to mechanical work output.

Ex: steam engine, steam power plant, jet engine, gas turbine power plant, diesel engine, and gasoline (petrol) engine etc.

On the basis of how thermal energy is being delivered to working fluid of the heat engine, Heat engine can be classified as




**Internal combustion engine:**

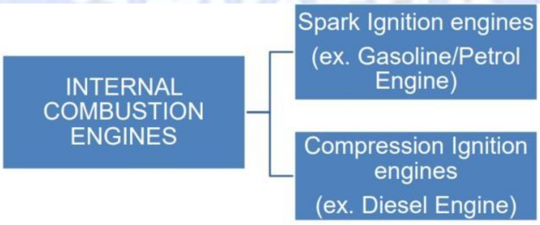
Combustion takes place within the working fluid of the engine.

- Thus fluid gets contaminated with combustion products.
- Petrol engine is an example of internal combustion engine, where the working fluid is a mixture of air and fuel.

**External combustion engine:**

Working fluid gets energy from outside through some heat exchanger (Boiler)

- Thus the working fluid does not come in contact with combustion products.
- Steam engine is an example of external combustion engine, where the working fluid is steam.




**Spark ignition engine (SI engine):**

An engine in which the combustion process in each cycle is started by use of an external spark.

**Compression ignition engine (CI engine):**

An engine in which the combustion process starts when the air-fuel mixture self ignites due to high temperature in the combustion chamber caused by high compression.

**Advantages of Internal Combustion Engines:**

1. Greater mechanical simplicity.
2. Higher power output per unit weight because of absence of auxiliary units like boiler, condenser and feed pump.
3. Low initial cost.
4. Higher brake thermal efficiency as only a small fraction of heat energy of the fuel is dissipated to cooling system.
5. These units are compact and requires less space.
6. Easy starting from cold conditions

**Disadvantages of Internal Combustion Engines:**

1. IC engines cannot use solid fuels which are cheaper. Only liquid or gaseous fuel of given specification can be efficiently used. These fuels are relatively more expensive.
2. IC engines have reciprocating parts and hence balancing of them is problem and they are also susceptible to mechanical vibrations.

**Applications of Internal Combustion Engines:**

IC engines have many applications, including:

- Road vehicles (scooter, buses, motorcycle etc.)
- Aircraft
- Motorboats
- Locomotives

**Classification of I.C. Engines:**

The internal combustion engines may be classified in many ways, but the following are important from the subjec3 point of view:

1. According to the type of fuel used
(a) Petrol engines, (b) Diesel engines and (c) Gas engines.

2 According to the method of igniting the fuel
(a) Spark ignition engines (briefly written as SI. engines), (b) Compression ignition engines (briefly written as C.I. engines.

3. According to the number of strokes per cycle
(a) Four stroke cycle engines, and (b) Two stroke cycle engines.

4. According to the cycle of operation
(a) Otto cycle (b) Diesel cycle and (c) Dual combustion cycle.

5. According to the speed of the engine

(a) Slow speed engines, (b) Medium speed engines, and (c) High speed engines.

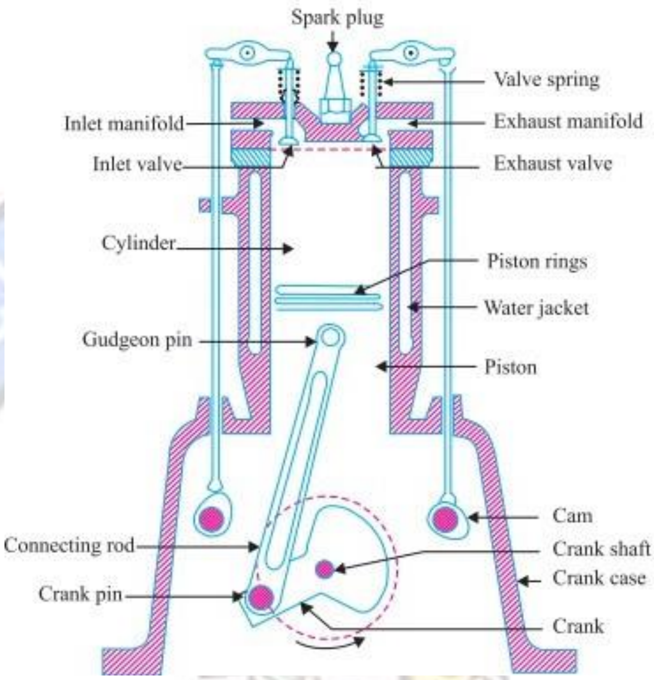
6. According to the cooling system

(a) Air-cooled engines, (b) Water-cooled engines, and (c) Evaporative cooling engines.

7. According to the number of cylinders

(a) Single cylinder engines, and (b) Multi-cylinder engines.

## Main Components of IC Engines:




**IC Engine components**

**Cylinder:** It is one of the most important parts of the engine, in which the piston moves to and fro in order to develop power. For ordinary engines, the cylinder is made of ordinary cast iron. But for heavy duty engines, it is made of steel alloys or aluminium alloys.

**Cylinder head:** The top end of the cylinder is covered by cylinder head over which inlet and exhaust valve, spark plug or injectors are mounted. A copper or asbestos gasket is provided between the engine cylinder and cylinder head to make an air tight joint.

**Piston:** It is considered as the heart of an I.C. engine, whose main function is to transmit the force exerted by the burning of charge to the connecting rod. The pistons are generally made of aluminium alloys which are light in weight. They have good heat conducting property and also greater strength at higher temperatures.

**Piston rings:** These are housed in the circumferential grooves provided on the outer surface of the piston and made of steel alloys which retain elastic properties even at high temperature.2 types of rings- compression and oil rings. Compression ring is upper ring of the piston which provides air tight seal to prevent leakage of the burnt gases into the lower portion. Oil ring is lower ring which provides effective seal to prevent leakage of the oil into the engine cylinder.

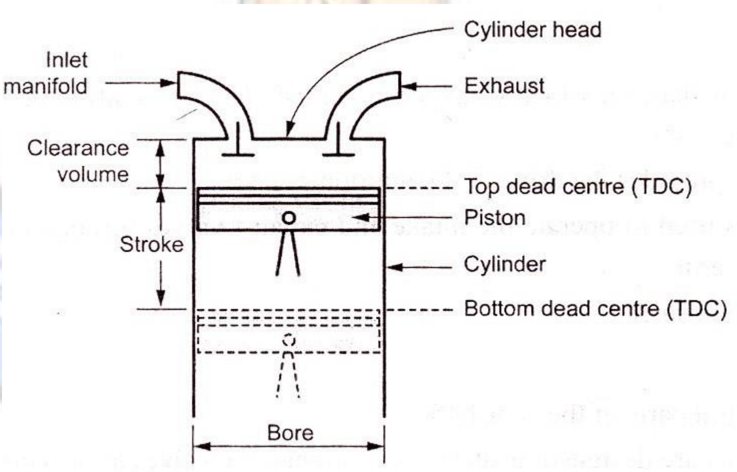
**Connecting rod:** It is a link between the piston and crankshaft, whose main function is to transmit force from the piston to the crankshaft. Moreover, it converts reciprocating motion of the piston into circular motion of the crankshaft, in the working stroke.

**Crank shaft:** In is considered as the backbone of an I.C. engine whose, function is to convert the reciprocating motion of the piston into the rotary motion with the help of connecting rod.

**Crank case:** It is a cast iron case, which holds the cylinder and crankshaft of an I.C. engine. It also serves as a sump for the lubricating oil. **Terminology used in IC engine:**

**Cylinder bore (D):** The nominal inner diameter of the working cylinder. **Stroke:** Distance traveled by the piston from one extreme position to the other: TDC to BDC or BDC to TDC.

**Top Dead Centre (T.D.C):** The top most position of the piston towards cover end side of the cylinder” is called top dead centre. In case of horizontal engine, it is called as inner dead




centre.

**Bottom Dead Centre (B.D.C):** The lowest position of the piston towards the crank end side of the cylinder is called bottom dead centre. In case of horizontal engine, it is called outer dead centre.

**Clearance volume:** It is the minimum volume of the cylinder available for the charge (air or air fuel mixture) when the piston reaches at its outermost point (top dead center or outer dead center) during compression stroke of the cycle.

**Swept Volume:** The volume swept by the piston during one stroke is called the swept volume or piston displacement. Swept volume is the volume covered by the piston while moving from TDC to BDC.

**Compression ratio:** The ratio of total volume to clearance volume of the cylinder is the compression ratio of the engine. – Typically compression ratio for SI engines varies from 8 to 12 and for CI engines it varies from 12 to 24. **Two-stroke and Four - stroke Cycle Engines:**

In a two-stroke engine, the working cycle is completed in two strokes of the piston or one revolution of the crankshaft. This is achieved by carrying out the Suction and compression processes in one stroke (or more precisely in inward stroke), expansion and exhaust processes in the second stroke (or more precisely in outward stroke).

In a four-stroke engine, the working cycle is completed in four-strokes of the piston or two-revolutions of the crankshaft. This is achieved by carrying out suction, compression, expansion/power and exhaust processes in each stroke.

## Advantages and Disadvantage of Two-stroke over Four-stroke Cycle Engines:

**Advantages:**

1. For the same power developed, a two-stroke cycle engine is lighter, less bulky and occupies less floor area.
2. As the number of working strokes in a two-stroke cycle engine are twice than the tour-stroke cycle engine, so the turning moment of a two-stroke cycle engine is more uniform. Thus it makes a two-stroke cycle engine to have a lighter flywheel and foundations. This also leads to a higher mechanical efficiency of a two-stroke cycle engine.
3. The initial cost of a two-stroke cycle engine is considerably less than a four-stroke cycle engine.
4. The mechanism of a two-stroke cycle engine is much simpler than a four-stroke cycle engine.
5. The Two-stroke cycle engines are much easier to start.

## Disadvantages:

1. Thermal efficiency of a two-stroke cycle engine is less than that a four- stroke cycle engine, because a two-stroke cycle engine has less compression ratio than that of a four-stroke cycle engine.

2. Overall efficiency of a two-stroke cycle engine is also less than that of a four-stroke cycle engine because in a two-stroke cycle, inlet and exhaust ports remain open simultaneously for some time. inspite of careful design, a small quantity of charge is lost from the engine cylinder.
3. In case of a two-stroke cycle engine, the number of power strokes are twice as those of a four-stroke cycle engine. Thus the capacity of the cooling system must be higher. Beyond a certain limit, the cooling capacity offers a considerable difficulty. Moreover, there is greater wear and tear in a two-stroke cycle engine.
4. The consumption of lubricating oil is large in a two-stroke cycle engine because of high operating temperature.
5. The exhaust gases in a two-stroke cycle engine creates noise, because of short time available for their exhaust.

**Comparison of four stroke and two stroke engines:**

| S.No | Four-stroke engine | Two-stroke engine |
|---|---|---|
| 1 | Four stroke of the piston and two revolution of crankshaft | Two stroke of the piston and one revolution of crankshaft |
| 2 | One power stroke in every two revolution of crankshaft | One power stroke in each revolution of crankshaft |
| 3 | Heavier flywheel due to non-uniform turning movement | Lighter flywheel due to more uniform turning movement |
| 4 | Power produce is less | Theoretically power produce is twice than the four stroke engine for same size |
| 5 | Heavy and bulky | Light and compact |
| 6 | Lesser cooling and lubrication requirements | Greater cooling and lubrication requirements |
| 7 | Lesser rate of wear and tear | Higher rate of wear and tear |
| 8 | Contains valve and valve mechanism | Contains ports arrangement |
| 9 | Higher initial cost | Cheaper initial cost |
| 10 | Volumetric efficiency is more due to greater time of induction | Volumetric efficiency less due to lesser time of induction |
| 11 | Thermal efficiency is high and also part load efficiency better | Thermal efficiency is low, part load efficiency lesser |
| 12 | It is used where efficiency is important.<br><br>Ex-cars, buses, trucks, tractors, industrial engines, aero planes, power generation etc | It is used where low cost, compactness and light weight are important.<br><br>Ex-lawn mowers, scooters, motor cycles, mopeds, propulsion ship etc. |

**Comparison of Petrol (S.I) and Diesel engine (C.I):**

| S.No | Petrol engine | Diesel engine |
|---|---|---|
| 1 | A petrol engine draws a mixture of petrol and air during suction stroke. | A diesel engine draws only air during suction stroke. |
| 2 | The carburetor is employed to mix air and petrol in the required proportion and to supply it to the engine during suction stroke. | The injector or atomizer is employed to inject the fuel at the end of compression stroke. |
| 3 | Pressure at the end of compression is about 10 bar | Pressure at the end of compression is about 35 bar |
| 4 | The charge (i.e. petrol and air mixture) is ignited with the help of spark plug | The fuel is injected in the form of fine spray. The temperature of the compressed air (about 600'C at a pressure of about 35 bar) is sufficiently high to ignite the fuel. |
| 5 | The combustion of fuel takes place approximately at constant volume. In other words, it works on Otto cycle. | The combustion of fuel takes place approximately at constant pressure. In other words, it works on Diesel cycle. |
| 6 | A petrol engine has compression ratio approximately from 6 to 10. | A diesel engine has compression ratio approximately from 15 to 25. |
| 7 | The starting is easy due to low compression | The starting is little difficult due to high compression ratio. |
| 8 | As the compression ratio is low, the petrol engines are lighter and cheaper | As the compression ratio is high, the diesel engines are heavier and costlier |
| 9 | The running cost of a petrol engine is high because of the higher cost of petrol. | The running cost of diesel engine is low because of the lower cost of diesel. |
| 10 | The maintenance cost is less. | The maintenance cost is more. |
| 11 | The thermal efficiency is upto about 26%. | The thermal efficiency is upto about 40%. |
| 12 | Over heating trouble is more due to low thermal efficiency. | Over heating trouble is less due to high thermal efficiency. |
| 13 | These are high speed engines. | These are relatively low speed engines. |
| 14 | The petrol engines are generally employed in light duty vehicles such as scooters, motorcycles, cars. These are also used in aeroplanes. | The diesel engines are generally employed in heavy duty vehicles like buses, trucks, and earth moving machines etc |

**Four-Stroke Petrol Engine (Four stroke S.I. engine):**

The four-stroke cycle petrol engines operate on Otto (constant volume) cycle. Since ignition in these engines is due to a spark, they are also called spark ignition engines. The four different strokes are:

i) Suction stroke

ii) Compression stroke

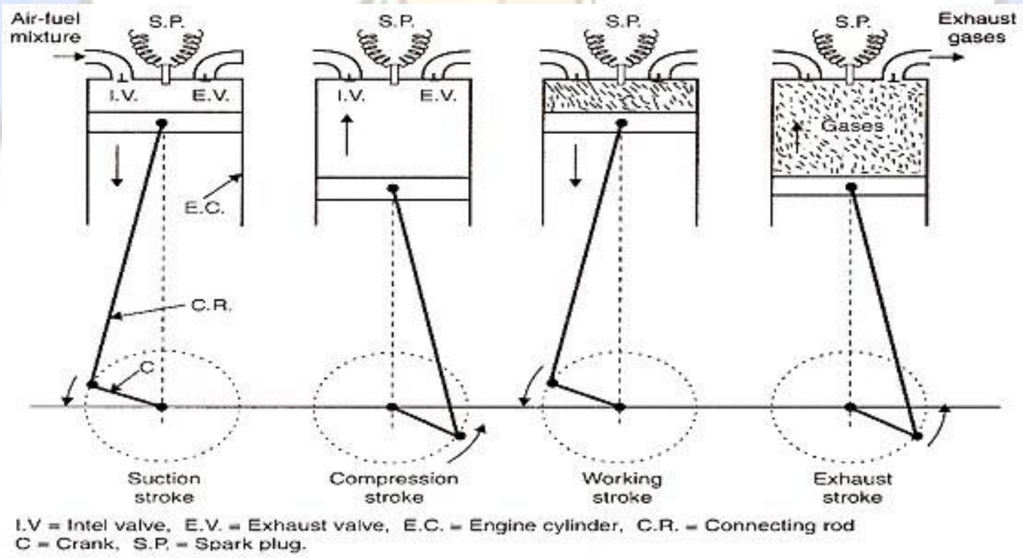
iii) Working or power or expansion stroke

iv) Exhaust stroke.

**Suction Stroke:** In this stroke, the inlet valve opens and charge is sucked into the cylinder as the piston moves downward from top dead centre (T.D.C,). It continues till the piston reaches its bottom dead centre (B.D.C.) as shown in below figure.

**Compression stroke:** In this stroke, both the inlet and exhaust valves are closed and the charge is compressed as the piston moves upwards from
B.D.C. to T.D.C. As a result of compression, the pressure and temperature of the charge increases considerably (the actual values depend upon the compression ratio). This completes one revolution of the crankshaft. The compression stroke is shown in below figure.

**Expansion or working stroke:** Shortly before the piston reaches T.D.C. (during compression stroke), the charge is ignited with the help of a spark plug. It suddenly increases the pressure and temperature of the products of combustion but the volume, practically, remains constant. Due to the rise in pressure, the piston is pushed down with a great force. The hot burnt gases expand due to high speed of the piston. During this expansion, some of the heat energy produced is transformed into mechanical work. It may be noted that during this working stroke, as shown in above figure, both the valves are closed and piston moves from T.D.C. to B.D.C.



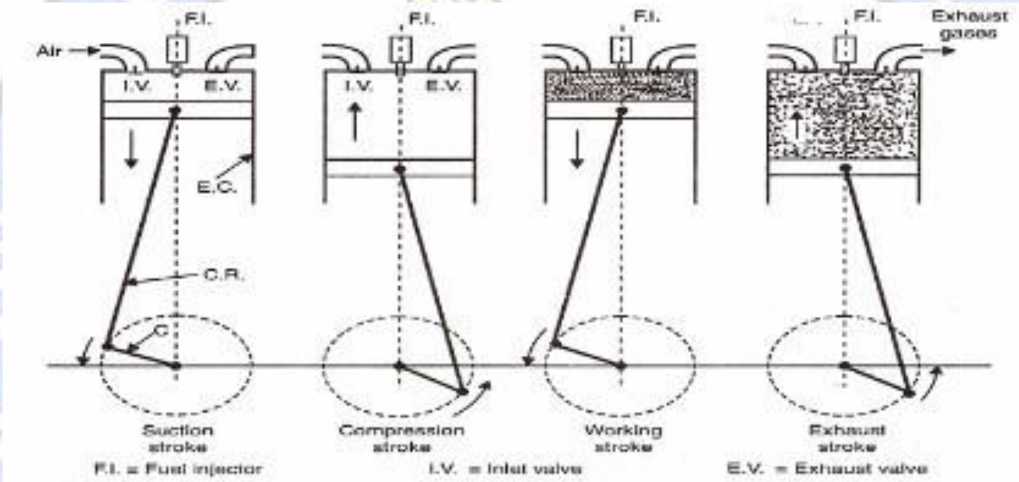

**Exhaust stroke:** In this stroke, the exhaust valve is open as piston moves from B.D.C. to T D. C. This movement of the piston pushes out the products of combustion, from the engine cylinder and are exhausted through the exhaust valve into the atmosphere, as shown in above figure. This completes the cycle, and the engine cylinder is ready to suck the charge again.

**Note:** The four stroke cycle petrol engine are usually employed in light vehicles such as cars. Jeeps and aeroplanes.

## Four Stroke Diesel Engine (Four Stroke C.I Engine):

**Suction or charging stroke:** In this stroke, the inlet valve opens and pure air is sucked into the cylinder as the piston moves downwards from the top dead centre (TDC). It continues till the piston reaches its bottom dead centre (BDC) as shown in below figure.

**Compression stroke:** In this stroke, both the valves are closed and the air is compressed as the piston moves upwards from BDC to TDC. As a result of compression, pressure and temperature of the air increases considerably (the actual value depends upon the compression ratio). This completes one revolution of the crank shaft the compression stroke is shown in below figure.



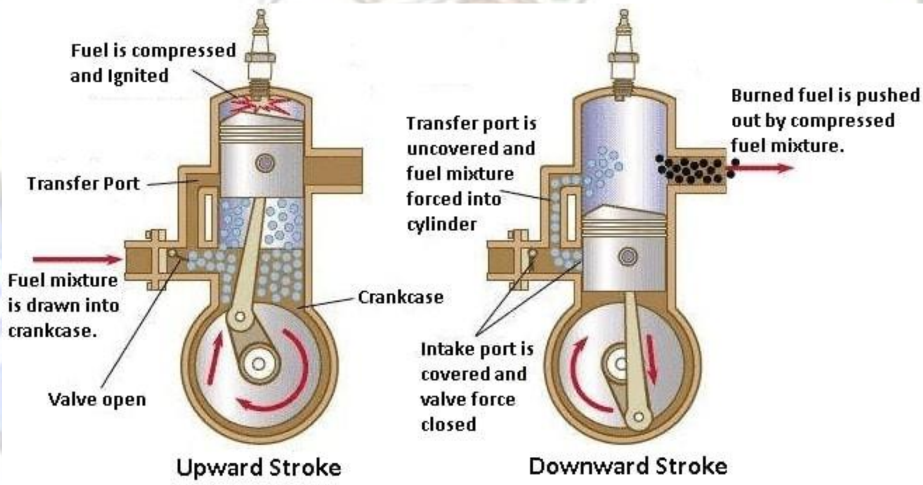

**Expansion or working stroke:** Shortly before the piston reaches the TDC (during the compression stroke), fuel oil is injected in the form of very line spray into the engine cylinder, through the nozzle, known as fuel injection valve. At this moment, temperature of the compressed air is sufficiently high to ignite the fuel suddenly increases the pressure and temperature of the products of combustion. The fuel oil is continuously injected for a fraction of the revolution. The fuel oil is assumed to be burnt at constant pressure. Due to increased pressure, the piston is pushed down with a great forte. The hot burnt gases expand due to high speed of the piston. During this expansion, some of the heat energy is transformed into mechanical work. It may be noted that during this working stroke, both the valves are closed and the piston moves from TDC to BDC.

**Exhaust stroke:** In this stroke, the exhaust valve is open as the piston moves from BDC to TDC. This movement of the piston pushes out the products of combustion from the engine cylinder through the exhaust valve into the atmosphere. This completes the cycle and the engine cylinder is ready to suck the fresh air again.

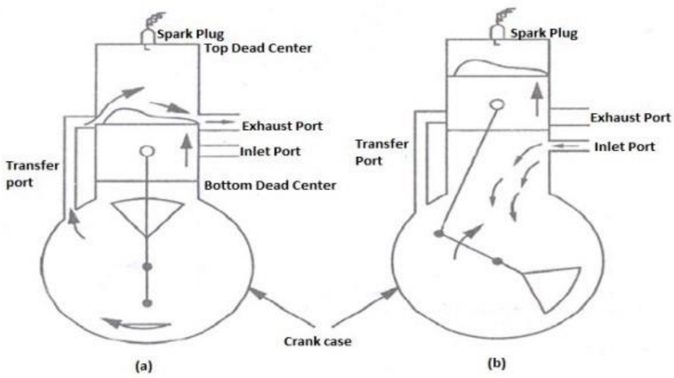
**Note:** The four stroke cycle diesel engines are generally employed in heavy vehicles such as buses, trucks, tractors, pumping sets, diesel locomotives and in earth moving machinery.

## Two-stroke Cycle Petrol Engine:

In this cycle, the suction, compression, expansion and exhaust takes place during two strokes of the piston. It means that there is one working stroke after every revolution of the crank shaft. A two stroke engine has ports instead of valves i.e. suction port, transfer port and exhaust port. These ports are covered and uncovered by the up and down movement of the piston. The top of the piston is deflected to avoid mixing of fresh charge with exhaust gases. The exhaust gases are expelled out from the engine cylinder by the fresh charge of fuel entering the cylinder. The mixture of air and petrol is ignited by an spark produced at the spark plug. The two stroke of the engine are.




**(Or)**



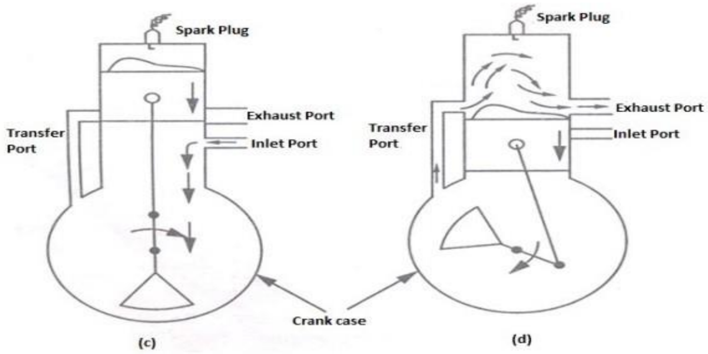



Fig-TWO STROKE CYCLE PETROL (S.I.) ENGINE-

**Upward Stroke (Suction + Compression):**

Assuming the piston to be at the BDC position. The inlet port is covered by the piston whereas the transfer port and exhaust port are uncovered. The piston moves from BDC to TDC. The air petrol mixture enters the cylinder. On the upward movement of the piston, first of all the transfer port is covered and then immediately, the exhaust port is covered. Simultaneously the suction port also gets uncovered, the upward movement of the piston helps to compress the air fuel mixture at the top and creates partial vacuum at the bottom in the crankcase which gets filled with air fuel mixture by the atmospheric pressure. At the end of the stroke, the piston reaches the TDC position completing the compression stroke as shown in Fig. (a) and (b).

### Downward Stroke (Power + Exhaust):

Just before the completion of the compression stroke, the compressed charge is ignited in the combustion chamber, by means of an electric spark produced by the spark plug. Combustion of air fuel mixture pushes the piston in the downward direction, on the power stroke producing useful work. The movement of the power action is over, the exhaust port is uncovered. The exhaust gases escape to the atmosphere. Further movement of the piston covers the inlet port and the fresh charge is compressed in the crankcase. Simultaneously the transfer port is also uncovered. The compressed mixture of air fuel enters the combustion chamber. The deflected shape of the piston avoids inter-mixing of the fresh charge and exhaust gases i.e. the fresh charge rises to the top of the cylinder and pushes out most of the exhaust gases. Thus the three actions, power, exhaust and induction are completed from TDC to BDC position completing one cycle i.e. two stroke of the piston and one revolution of the crankshaft as shown in Fig. (c) and (d).

### Two-stroke Cycle Diesel Engine:

**1st stroke:** To start with let us assume the piston to be at its B.D.C. position (Fig. a). The arrangement of the ports is such that the piston performs the two jobs simultaneously.

As the piston starts rising from its B.D.C. position, if closes the transfer port and the exhaust port. The air which is already there in the cylinder is compressed (Fig. b).

At the same time with the upward movement of the piston, vacuum is created in the crank case. As soon as the inlet port is uncovered, the fresh air is sucked in the crank case. The charging is continued until the crank case and the space in the cylinder beneath the piston is filled (Fig. c) with the air. At the end of the stroke, the piston reaches the T.D.C. Position.

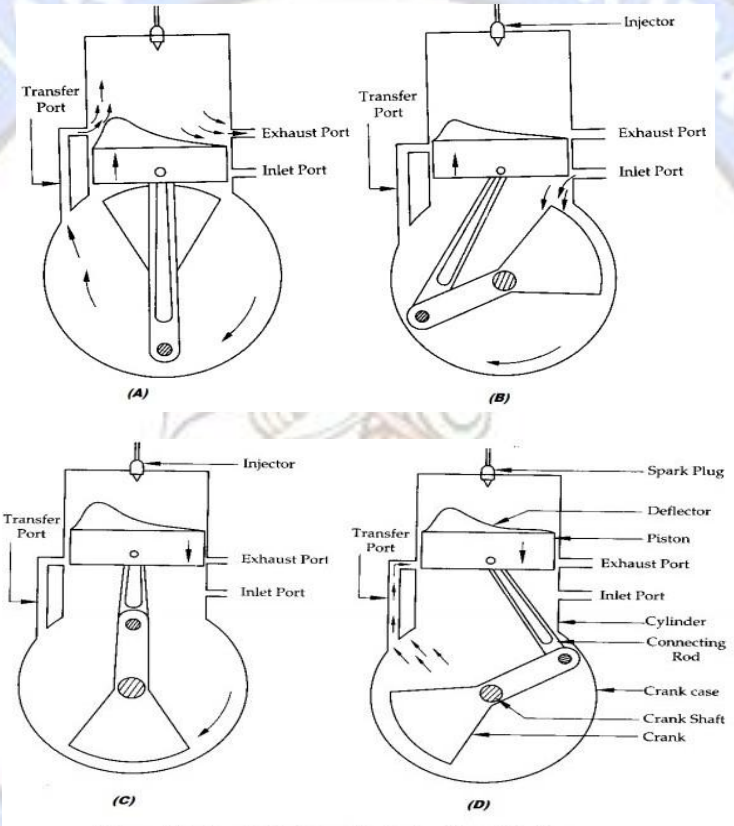



*Figure- Working Principle of 2-stroke Diesel Engine*

**2nd stroke:** Slightly before the completion of the compression stroke, a very fine sprays of diesel injected into the compressed air. The fuel ignites spontaneously.

Pressure is exerted on the crown of the piston due to the combustion of the air and the piston is pushed in the downward direction producing some useful power (Fig. c). The downward movement of the piston will first close the inlet port and then it will compress the air already sucked in the crank case.

Just the end of power stroke, the piston uncovers the exhaust port and the transfer port simultaneously. The expanded gases start escaping through the exhaust port and at the same time transfer port (Fig. d) and thus the cycle is repeated again.

The fresh air coming into the cylinder also helps in exhausting the burnt gases out of the cylinder through the exhaust port (Fig. d). This is known as scavenging.

## Components of Electrical Vehicles (EV):

Electric vehicles (EVs) are a type of vehicle that uses electricity stored in batteries to power an electric motor, rather than relying on internal combustion engines like traditional gasoline or diesel vehicles. The main components of electric vehicles include:

1. **Electric Motor**: The electric motor is the primary source of propulsion in an EV. It converts electrical energy from the battery into mechanical energy to drive the wheels. There are different types of electric motors used in EVs, such as AC induction motors and permanent magnet motors.
2. **Battery Pack**: The battery pack is a crucial component of an EV. It stores electrical energy in the form of chemical energy and provides power to the electric motor. Lithium-ion batteries are commonly used in modern EVs due to their high energy density and efficiency.
3. **Charging Port**: Electric vehicles need to be charged to operate. They have a charging port that allows the vehicle to be connected to external power sources, such as charging stations or home chargers. Charging times and options vary depending on the vehicle and charger type.
4. **Power Electronics**: Power electronics play a vital role in converting and controlling the flow of electrical energy between the battery and the electric motor. They include components like inverters, converters, and controllers, which manage the voltage and current to optimize performance.
5. **Onboard Charger**: This component is responsible for converting alternating current (AC) from the charging source into direct current (DC)to charge the vehicle's battery. The size and capacity of the onboard charger can vary among different EV models.
6. **Thermal Management System**: EVs generate heat during operation, especially the battery and electric motor. A thermal management system helps regulate and maintain the temperature within the optimal range to ensure battery longevity and efficiency.

7. **Electric Vehicle Controller**: The controller manages various functions of the EV, such as acceleration, regenerative braking, and energy management. It also communicates with other systems in the vehicle, like the battery management system.

8. **High-Voltage Wiring**: EVs use high-voltage wiring to carry electrical power from the battery to the electric motor and other components. This wiring is designed to handle the higher voltages used in electric vehicles safely.

9. **Regenerative Braking System**: Electric vehicles often in corporate regenerative braking systems that capture energy during braking and convert it back into electrical energy to recharge the battery. This system helps improve energy efficiency.

10. **Auxiliary Systems**: Similar to traditional vehicles, electric vehicles have auxiliary systems such as power steering, air conditioning, and entertainment systems. These systems are powered by the vehicle's battery or a separate 12-voltbattery.

11. **Safety Systems**: EVs are equipped with safety systems, including airbags, antilock braking systems (ABS), stability control, and collision avoidance technologies, to ensure passenger safety.

12. **Body and Chassis**: The body and chassis of an EV are designed to accommodate the electric drive train components while providing structural integrity and crash protection.

13. **Electric Vehicle Software**: Modern EVs rely on sophisticated software to manage various aspects of the vehicle, including battery state-of-charge, energy consumption, regenerative braking optimization.

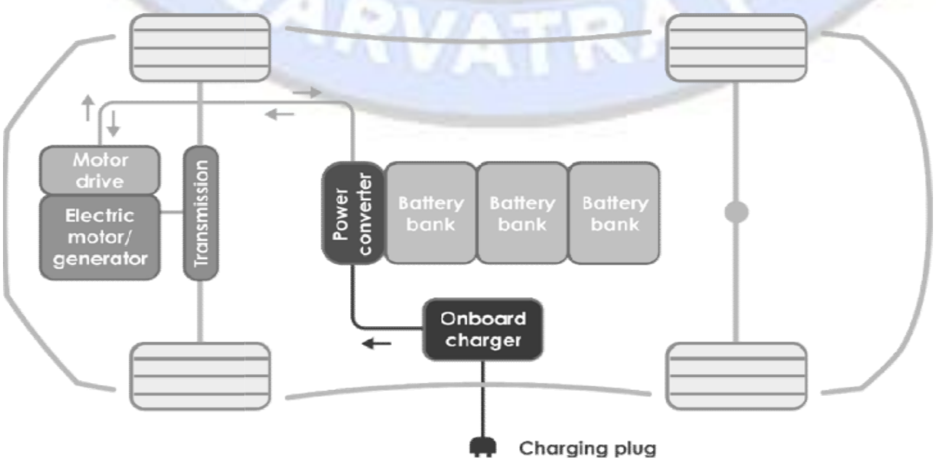



**Fig. Schematic diagram of an electric vehic**

le

and performance

## Components of Hybrid Vehicles:

Hybrid vehicles combine an internal combustion engine (usually gasoline) with an electric motor and battery system to improve fuel efficiency and reduce emissions. The components of hybrid vehicles can vary depending on the type of hybrid system (e.g., mild hybrid, full hybrid, plug- in hybrid), but here are the key components commonly found in hybrid vehicles:

1. **Internal Combustion Engine** (ICE): Hybrid vehicles have a traditional gasoline or, in some cases, a diesel engine. This engine can vary in size and power, depending on the vehicle's design.
2. **Electric Motor**: Hybrids are equipped with an electric motor that assists the internal combustion engine. The motor provides additional power during acceleration and can operate independently with the engine.
3. **Battery Pack**: Hybrid vehicles have a smaller battery pack compared to pure electric vehicles. This battery stores electrical energy and provides power to the electric motor. Battery chemistry and capacity can differ between hybrid models.
4. **Electric Generator**: In some hybrid systems, the internal combustion engine can act as a generator when needed. It can recharge the battery or provide power to the electric motor.
5. **Power Split Device** (Transmission): Many hybrids use a power split device, which is a specialized transmission that allows the internal combustion engine and electric motor to work together efficiently. This device manages the power flow between the engine, motor, and wheels.
6. **Regenerative Braking System**: Hybrids utilize regenerative braking to capture and store energy that is normally lost as heat during braking. This recovered energy is used to recharge the battery.
7. **Electric Drive Unit (EDU)**: The electric drive unit includes the electric motor, power electronics (inverters and converters), and control systems. It manages the flow of electricity between the battery and the motor.
8. **Hybrid Control System**: This system controls the operation of the internal combustion engine, electric motor, and other components to

optimize fuel efficiency and performance. It decides when to use electric power, gasoline power, or both.

9. **Transmission:** Hybrid vehicles typically have automatic transmissions to provide smooth power delivery. Some hybrids use continuously variable transmissions (CVTs) to optimize fuel efficiency.

10. **Fuel Tank**: Hybrids still rely on gasoline, so they have a fuel tank to store gasoline. However, the tank is usually smaller than in conventional vehicles due to the improved fuel efficiency of the hybrid system.

11. **Auxiliary Systems:** Similar to traditional vehicles, hybrids have auxiliary systems such as power steering, air conditioning, and entertainment systems. These systems are powered by the vehicle's battery or the internal combustion engine.

12. **Charging System**: Hybrid vehicles do not need to be plugged in to charge the battery, as they rely on regenerative braking and the internal combustion engine to charge it. However, plug-in hybrid models have the ability to charge from an external power source.

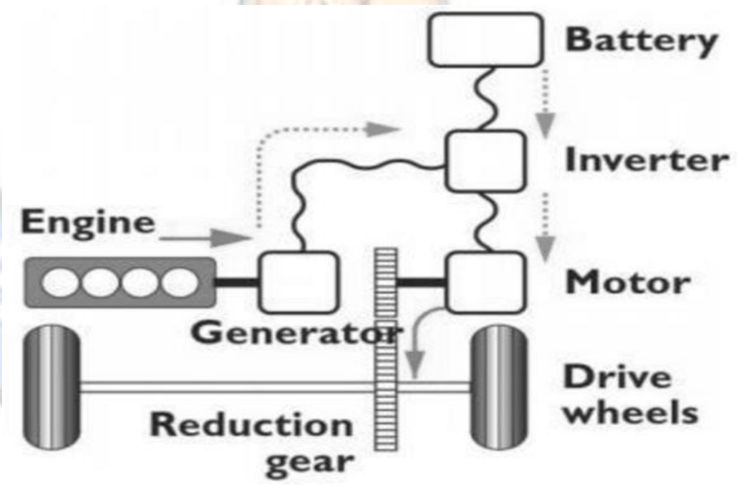



**Fig. Schematic diagram of a hybrid vehicle**

# UNIT – III

# POWER PLANT ENGINEERING

A power plant is assembly of systems or subsystems to generate electricity, i.e., power with economy and requirements. The power plant itself must be useful economically and environmental friendly to the society.

A power plant may be defined as a machine or assembly of equipment that generates and delivers a flow of mechanical or electrical energy. The main equipment for the generation of electric power is generator. When coupling it to a prime mover runs the generator, the electricity is generated.

There are mainly two types of sources of energy

1. Conventional Sources of Energy (Non-Renewable Sources of Energy)
2. Non-conventional (Renewable Sources of Energy).

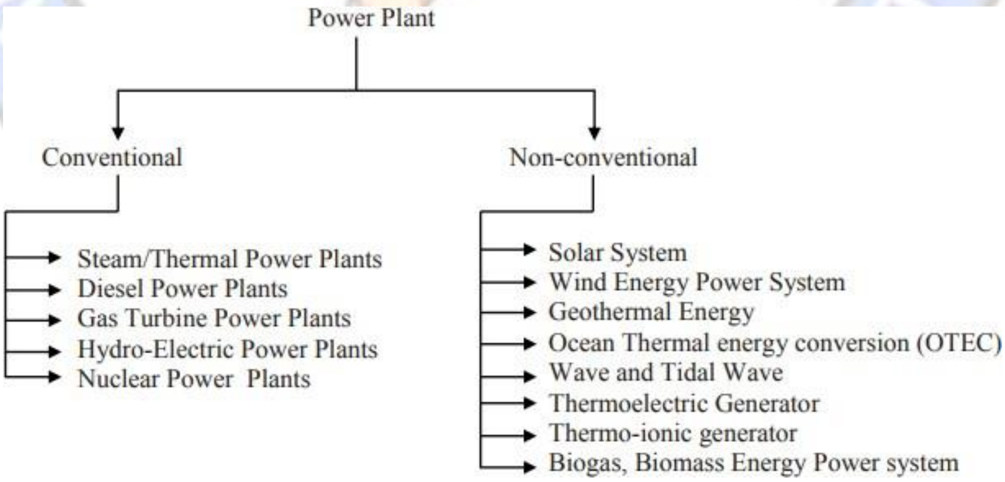
## Conventional Sources of Energy:

These resources are finite and exhaustible. Once consumed, these sources cannot be replaced by others. Examples include coal, timber, petroleum, lignite, natural gas, fossil fuels, nuclear fuels etc.

## Non-Conventional Sources of Energy:

These sources are being continuously produced in nature and are not exhaustible. Examples include wood, geothermal energy, wind energy, tidal energy, nuclear fusion, gobar gas, biomass, solar energy etc.

## Classification of Power Plants:




## STEAM POWER PLANT:

The steam power plant is an important source to produce the electricity. The major portion of electricity demand is fulfilled by this power plant. It is also called a thermal power plant. It provides the electricity required to different areas.

**What is Steam Power Plant**

It is the power plant which is used to generate electricity by the use of steam turbine. The major components of these power plants are boiler, steam turbine, condenser, and water feed pump.

## Construction or Layout of Steam Power Plant:

There are so many components present in the steam power plant which performs their specialized function for efficient working. The various component of the steam power plant are:

**Coal Storage:** It is the place where coal is stored which can be utilised when required.

**Coal Handling:** Here the coal is converted into the pulverised form before feeding to the furnace. A proper system is designed to transport the pulverised coal to the boiler furnace.

**Boiler:** It converts the water into high pressure steam. It contains the furnace inside or outside the boiler shell. The combustion of coal takes place in the furnace.

**Air-preheater:** It is used to pre-heat the air before entering into the boiler furnace. The pre heating of air helps in the burning of fuel to a greater extent. It takes the heat from the burnt gases from the furnace to heat the air from the atmosphere.

**Economiser:** As its name indicates it economises the working of the boiler. It heats the feed water to a specified temperature before it enters into the boiler drum. It takes the heat from the burnt gases from the furnace to do so.

**Turbine:** It is the mechanical device which converts the kinetic energy of the steam to the mechanical energy.

**Generator:** It is coupled with the turbine rotor and converts the mechanical energy of the turbine to the electrical energy.

**Ash Storage:** It is used to store the ash after the burning of the coal.

**Dust Collector:** It collects the dust particle from the burnt gases before it is released to the chimney.

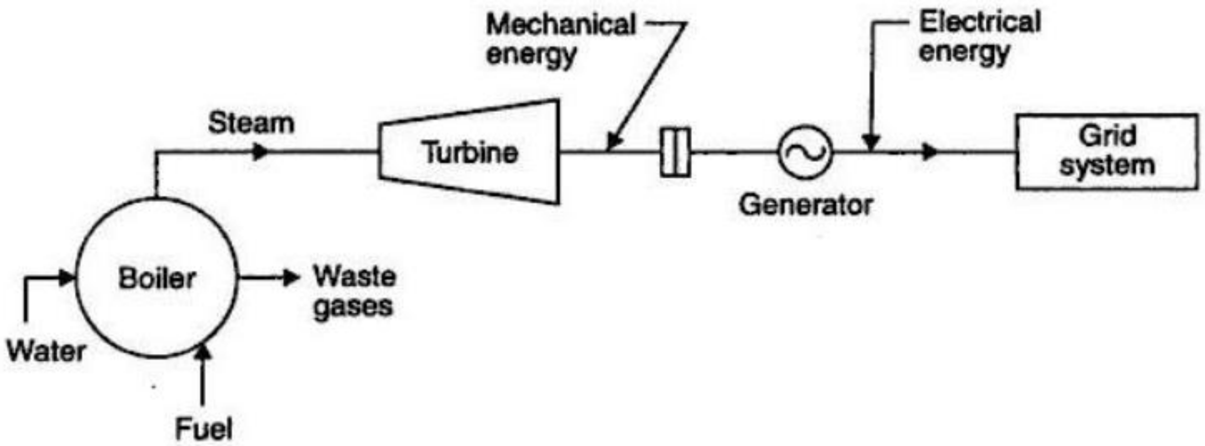
**Condenser:** It condensate the steam that leaves out turbine. It converts the low pressure steam to water. It is attached to the cooling tower.

**Cooling Tower:** It is a tower which contains cold water. Cold water is circulates to the condenserfor the cooling of the residual steam from the turbine.

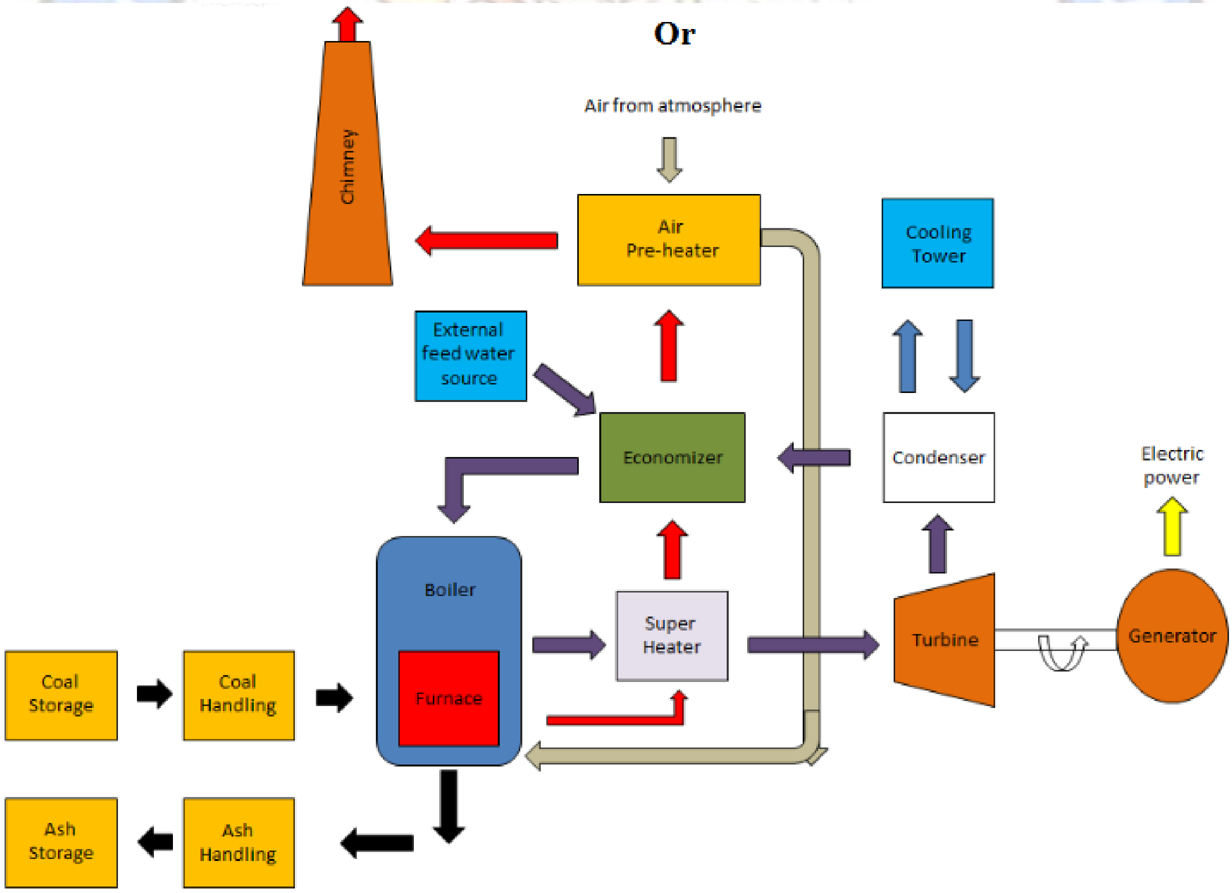
**Chimney:** It is used to release the hot burnt gases or smoke from the furnace to the environment at appropriate height. The height of the tower is very high such that it can easily throw the smoke and exhaust gases at the appropriate height. And it cannot affect the population living near the steam power plant.

**Feed Water Pump:** It is used to transport the feed water to the boiler.

## Working of Steam Power Plant:




**Or**




In the steam power plant the pulverised coal is fed into the boiler and it is burnt in the furnace. The water present in the boiler drum changes to high pressure steam. From the boiler the high pressure steam passed to the superheater where it is again heated upto its dryness. This superheated steam strikes the turbine blades with high speed and the turbine starts rotating at high speed. A generator is attached to the rotor of the turbine and as the turbine rotates it also rotates with the speed of the turbine. The generator converts the mechanical energy of the turbine into electrical energy. After striking on the turbine the steam leaves the turbine and enters into the condenser. The steam gets condensed with the help of cold water from the cooling tower. The condensed water with the feed water enters into the economiser. In the economiser the feed water gets heated up before entering into the boiler. This heating of water increases the efficiency of the boiler. The exhaust gases from the furnace pass through the superheater, economiser and air pre-heater. The heat of this exhaust gases is utilised in the heating of steam in the superheater, feed water in the economiser and air in the air pre-heater. After burning of the coal into the furnace, it is transported to ash handling plant and finally to the ash storage

**Site selection of steam power plant:**

The site selection of steam power plant depends upon various factors.

**Cost of the land:** The cost of the land which is selected for the installation should be minimum or economical.

**Population density of the land:** The distance of the steam power plant from the public area should be at appropriate distance. So that in case of any failure or hazard happen in the plant, the population of the area near to the power plant should not be affected.

**Availability of water sources:** There should be a plenty of water sources in the selected area. Since the power plant requires a large amount of water for the generation of steam.

**Availability of fuel:** The availability of required fuel (coal) should be there because withoutfuel the plant will not work.

**Type of land:** The land which is selected for the power plant installation should be plain enough and it is suitable for the strong foundation for the various machinery of the plant.

**Scope for the future demand:** The size of the land should be such that it is capable for thehandling of future power demand.

**Availability of Ash handling facility:** Proper ash handling facility should be available near the power plant to minimize the adverse effect of the ash produced in the steam power plant.

**Availability of transportation facility:** The transportation facility is must in the installation for the power plant, because any material cannot be transported to the power plant form its required location in lack of transport. There should be easy availability of proper transportation facility atthe selected site.

## Characteristics of Steam Power Plant:

The desirable characteristic for a steam power plant are as follows:

- ✓ Higher efficiency.
- ✓ Lower cost.
- ✓ Ability to burn coal especially of high ash content, and inferior coals.
- ✓ Reduced environmental impact in terms of air pollution.
- ✓ Reduced water requirement.
- ✓ Higher reliability and availability.

## Advantages of Steam Power Plant:

- ➢ Less initial cost as compared to other generating stations.
- ➢ It requires less land as compared to hydro power plant.
- ➢ The fuel (i.e. coal) is cheaper.
- ➢ The cost of generation is lesser than that of diesel power plants.

## Disadvantages of Steam Power Plant:

- ➢ It pollutes the atmosphere due to the production of large amount of smoke. This is one ofthe causes of global warming.
- ➢ The overall efficiency of a thermal power station is low (less than 30%).
- ➢ Requires long time for errection and put into action.
- ➢ Costlier in operating in comparison with that of Hydro and Nuclear power plants.
- ➢ Requirement of water in huge quantity

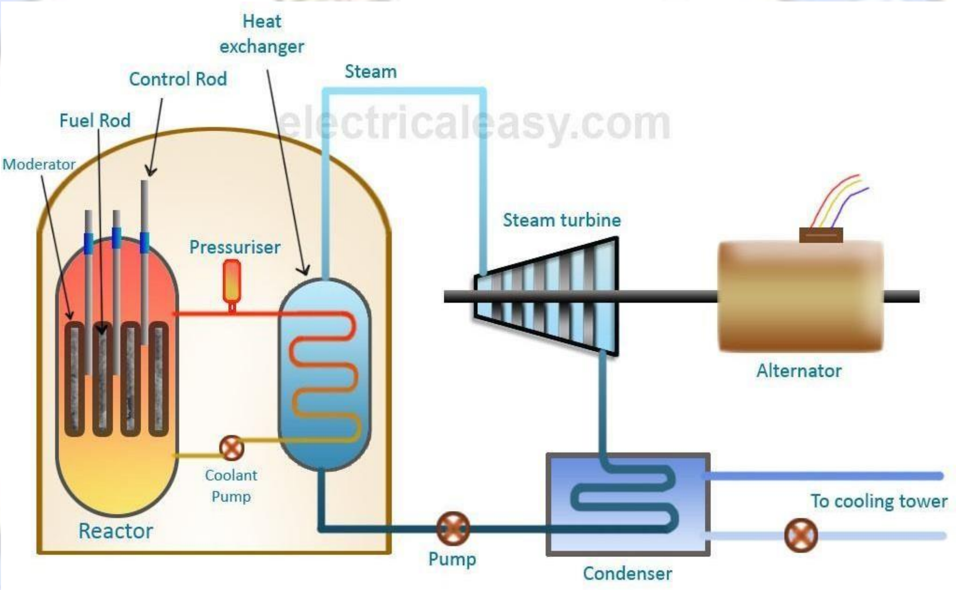
# NUCLEAR POWER PLANT:

## Introduction:

The heat energy in the nuclear power plant can be generated through a nuclear reaction or nuclear fission. The heavy elements of nuclear fission are Uranium/Thorium is carried out within a special device called a nuclear reactor. A huge amount of energy can be generated because of nuclear fission. The rest parts within the nuclear, as well as conventional thermal plants, are the same. The fission of 1 Kg Uranium generates heat energy which is equal to the energy generated through 4500 tons of high-grade coal. This significantly decreases the fuel transportation cost, so it is a major benefit of these plants. Worldwide, there are huge deposits of fuels existing; therefore, these plants can supply electrical energy continuously for hundreds of years. Nuclear power plants generate 10%of the electricity from the whole electricity in the world.

## What is a Nuclear Power Plant?

**Definition:** The power plant that is used to warm the water to generate steam then this steam can be used for rotating huge turbines for generating electricity. These plants use the heat to warm the water which is generated by nuclear fission. So the atoms in the nuclear fission will split into different smaller atoms for generating energy. The **nuclear power plant diagram** is shown below.




## Working of Nuclear Power Plant:

The elements like Uranium or Thorium are sued nuclear fission reaction of a nuclear reactor. Because of this fission, a huge amount of heat energy can be generated and it is transmitted to the coolant reactor. Here, the coolant is nothing but water, liquid metal otherwise gas. The water is heated to flow in a heat exchanger so that it changes into high-temperature steam. Then the steam which is produced is permitted to make a steam turbine run. Again the steam can be changed back into the coolant & recycled to use for the heat exchanger. So, the turbine and alternator are connected to produce electricity. By using a transformer, the electricity which is produced can be increased to use in long-distance communication.

## Components of Nuclear Power Plant:

In the above nuclear power plant block diagram, there are different components which include the following.

**Nuclear Reactor:** In a power plant, a nuclear reactor is an essential component like a heat source that includes the fuel & its reaction of nuclear chain including the waste products of nuclear. The nuclear fuel used in the nuclear reactor is Uranium & its reactions are heat generated in a reactor. Then, this heat can be transferred to the coolant of the reactor to generate heat to all the parts in the power plant. There are different types of nuclear reactors that are used in the manufacturing of plutonium, ships, satellites & aircraft for research as well as medical purposes. The power plant includes not only includes the reactor and also includes turbines, generators, cooling towers, a variety of safety systems.

**Heat Exchanger:** In the heat exchanger, the primary coolant transfers heat to the secondary coolant (water). Thus water from the secondary loop is converted into steam. The primary system and secondary system are closed loop, and they are never allowed to mix up with each other. Thus, heat exchanger helps in keeping secondary system free from radioactive stuff. Heat exchanger is absent in boiling water reactors.

**Steam Turbine:** Generated steam is passed through a steam turbine, which runs due to pressure of the steam. As the steam is passed through the turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator through a rotating shaft.

**Alternator:** The steam turbine rotates the shaft of an alternator thus generating electrical energy. Electrical output of the alternator is the delivered to a step up transformer to transfer it over distances.

**Condenser:** The steam coming out of the turbine, after it has done its work, is then converted back into water in a condenser. The steam is cooled by passing it through a third cold water loop.

## Advantages:

- ✓ It uses less space compared with other power plants.
- ✓ It is extremely economical and generates huge electric power.
- ✓ It generates a huge amount of power in the process of each nuclear fission.
- ✓ It uses less fuel to generate huge energy.
- ✓ Its operation is reliable.

- ✓ When compared with steam power plants, it is very clean and neat.
- ✓ The operating cost is small.

## Disadvantages:

- ✓ The cost of primary installation is extremely high when compared with other powerstations.
- ✓ The nuclear fuel is expensive so recovering is difficult.
- ✓ High capital cost compare with other power plants.
- ✓ Technical knowledge is required to operate this plat. So maintenance, as well as salary,will be high.
- ✓ There is a chance of radioactive pollution.
- ✓ The requirement of cooling water is double compare with a steam power plant.

## Applications:

Nuclear energy is used in different industries all over the world for desalination of ocean water, production of hydrogen, district cooling/heating, the removal of tertiary oil resources & used in heat process applications like cogeneration, conversion of coal to liquids &help in the chemical feedstock synthesis.

## Site Selection:

1. **Availability of water.** At the power plant site an ample quantity of water should be available for condenser cooling and made up water required for steam generation. Therefore the site should be nearer toa river, reservoir or sea.
2. **Distance from load center.** The plant should be located near the load center. This will minimise the power losses in transmission lines.
3. **Distance from populated area.** The power plant should be located far away from populated area to avoidthe radioactive hazard.
4. **Accessibility to site.** The power plant should have rail and road transportation facilities.
5. **Waste disposal.** The wastes of a nuclear power plant are radioactive and there should be sufficient spacenear the plant site for the disposal of wastes.

## HYDRO ELECTRIC POWER PLANT:

When rain water falls over the earth's surface, it possesses potential energy relative to sea or ocean towards which it flows. If at a certain point, the water falls through an appreciable vertical height, this energy can be converted into shaft work. As the water falls through a certain height, its potential energy is converted into kinetic energy and this kinetic energy is converted to the mechanical energy by allowing the water to flow through the hydraulic turbine runner. This mechanical energy is utilized to run an electric generator which is

$$\text{Power} = W.Q.H.\eta \text{ watts}$$

where $W$ = Specific weight of water, $N/m^3$

$Q$ = rate of water flow, $m^3/sec.$

$H$ = Height of fall or head, m

$\eta$ = efficiency of conversion of potential energy into mechanical energy.

coupled to the turbine shaft. The power developed in this manner is given as:

Hydro projects are developed for the following purposes:

1. To control the floods in the rivers.
2. Generation of power.
3. Storage of irrigation water.
4. Storage of the drinking water supply.

A power plant that utilizes the potential energy of water for the generation of electrical energy is known as a **hydroelectric power plant**.

Hydroelectric power plants are generally located in hilly areas where dams can be built easily, and large water reservoirs can be made. In a hydropower plant, a water head is created by building a dam across a river or lake. From the dam, water is fed to a water turbine.

The water turbine changes the kinetic energy of the falling water into mechanical energy at the turbine shaft. In simple words, falling water spins the water turbine. The turbine drives the alternator coupled with it and converts mechanical energy into electrical energy. This is the basic “working principle of hydroelectric power plant.”

The main elements of a hydroelectric power plant are as follows:

**Catchment area:** The total area behind the dam in which water is collected and stream flow is obtained is known as the catchment area.

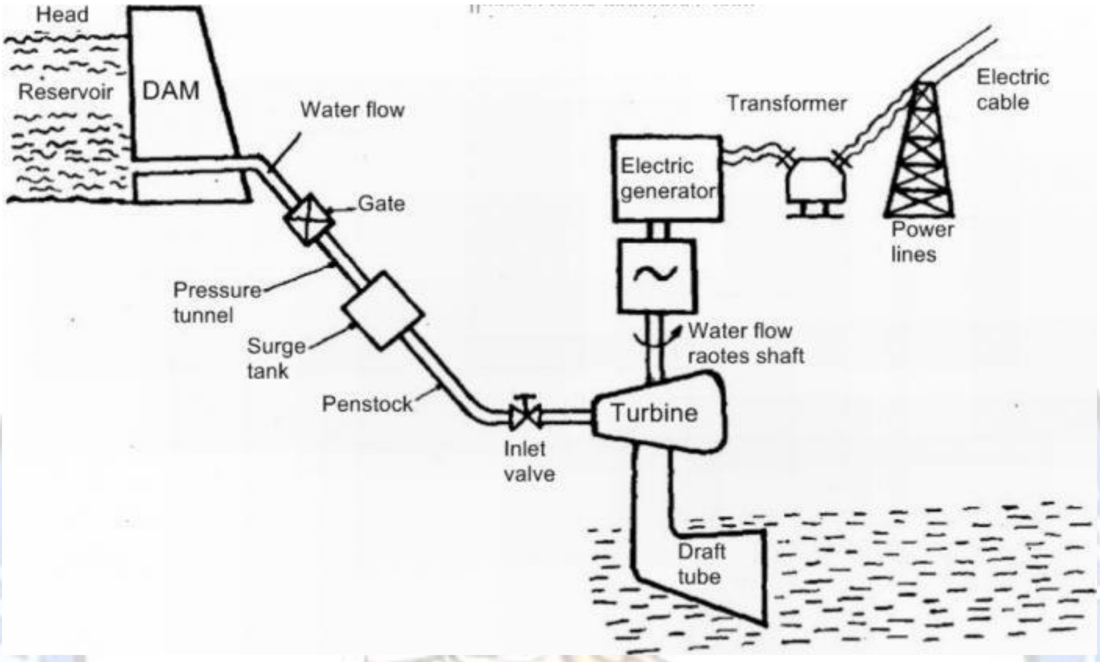
**Reservoir:** It is an integral part of the power plant, where water is stored and supplied to a water turbine continuously.

**Dam:** A dam is a barrier that stores water and creates a water head.

**Slip-way:** Due to heavy rainfall in the catchment area, the water level may exceed the storage capacity of the reservoir. It may affect the stability of the reservoir.

**Surge Tank:** It is a small tank (open at the top). It is provided to reduce the pressure surges in the conduit. It is located near the beginning of the conduit.

**Penstocks:** Penstocks are open or closed conduits that carry water to the turbines. They are generally made of RCC or steel. The RCC penstocks are suitable for low water heads (< 30 m). The steel penstocks are ideal for any head, as they can be designed according to water head or working pressure.




**Water turbines:** It works as an energy conversion device. It is a machine through which the potential energy of water is converted into the mechanical energy of shaft. The main types of water turbines are:

Before a water power site is considered for development, the following factors must be thoroughly analyzed:

1. The capital cost of the total plant.
2. The capital cost of erecting and maintaining the transmission lines and the annual power loss due to transformation and transmission of electric power since the water power plants are usually situated in hilly areas away from the load center.
3. The cost of electric generation compared with steam, oil or gas plants which can be conveniently set up near the load center.

**Advantages:**

✓ The plant can be run up and synchronized in a few minutes.

✓ The plant has no stand by losses.

✓ No fuel charges.

✓ The efficiency of the plant does not change with age.

**Disadvantages:**

- ✓ The capital cost of the plant is very high.
- ✓ The hydro-electric plant takes much longer in design and execution.
- ✓ These plants are usually located in hilly areas far away from the load center.
- ✓ Transformation and transmission costs are very high.

## DIESEL POWER PLANT:

Diesel power plants produce power from a diesel engine. Diesel electric plants in the range of 2 to 50 MW capacities are used as central stations for small electric supply networks and used as a standby to hydroelectric or thermal plants where continuous power supply is needed. Diesel power plant is not economical compared to other power plants.

The diesel power plants are cheaply used in the fields mentioned below.

1. Mobile electric plants
2. Standby units
3. Emergency power plants
4. Starting stations of existing plants
5. Central power station etc.

Figure shows the arrangements of the engine and its auxiliaries in a diesel power plant. The major components of the diesel power plant are:

**1) Engine:**

Engine is the heart of a diesel power plant. Engine is directly connected through a gear box to the generator. Generally two-stroke engines are used for power generation. Now a days, advanced super & turbo charged high speed engines are available for power production.

**2) Air supply system:**

Air inlet is arranged outside the engine room. Air from the atmosphere is filtered by air filter and conveyed to the inlet manifold of engine. In large plants supercharger/turbocharger is used for increasing the pressure of input air which increases the power output.

**3) Exhaust System:**

This includes the silencers and connecting ducts. The heat content of the exhaust gas is utilized in a turbine in a turbocharger to compress the air input to the engine.

**4) Fuel System:**

Fuel is stored in a tank from where it flows to the fuel pump through a filter. Fuel is injected to the engine as per the load requirement.

**5) Cooling system:**

This system includes water circulating pumps, cooling towers, water filter etc. Cooling water is circulated through the engine block to keep the temperature of the engine in the safe range.

**6) Lubricating system:**

Lubrication system includes the air pumps, oil tanks, filters, coolers and pipe lines. Lubricant is given to reduce friction of moving parts and reduce the wear and tear of the engine parts.

**7) Starting System:**

There are three commonly used starting systems, they are;

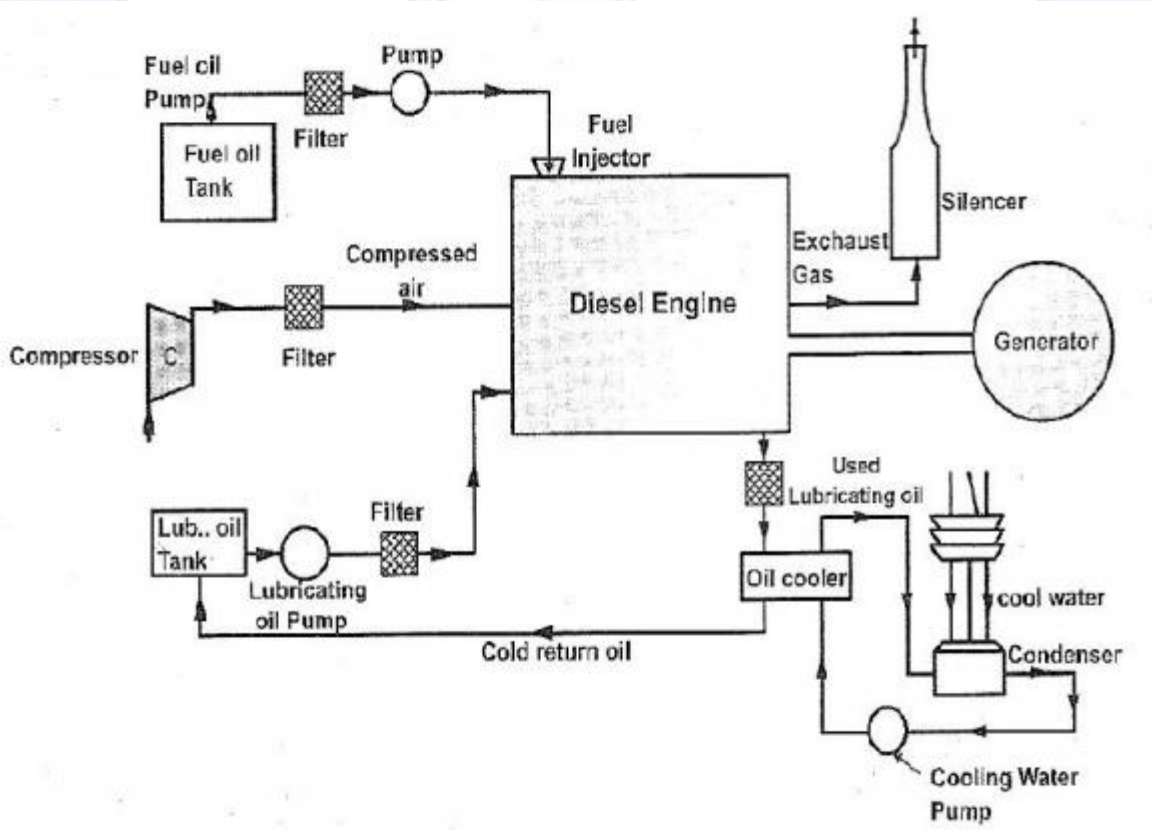
1) A petrol driven auxiliary engine

2) Use of electric motors.

3) Use of compressed air from an air compressor at a pressure of 20 Kg/cm.

**8) Governing system:**

The function of a governing system is to maintain the speed of the engine constant irrespective of load on the plant. This is done by varying fuel supply to the engine according to load



**Working of Diesel Power Plant**

In a diesel engine power plant, the combination of air and fuel serves as the working medium. During the suction stroke, atmosphere air will enter the combustion chamber under the influence of the injection pump, and fuel will be injected through the injection pump into the combustion chamber.

Due to high compression in the engine cylinders, air and fuel are mixed inside the engine, and the mixture is ignited by the combination of air and fuel.

There are two basic principles that apply to the diesel engine, the first of which is that thermal energy is converted into mechanical energy, and the second of which is that mechanical energy is converted into electrical energy to produce power by means of a generator or alternator.

**Advantages:**

1. Very simple design also simple installation.
2. Limited cooling water requirement.
3. Standby losses are less as compared to other Power plants.
4. Low fuel cost.
5. Quickly started and put on load.
6. Smaller storage is needed for the fuel.
7. Layout of power plant is quite simple.
8. There is no problem of ash handling.
9. Less supervision required.
10. For small capacity, diesel power plant is more efficient as compared to steam power plant.
11. They can respond to varying loads without any difficulty.

**Disadvantages:**

1. High Maintenance and operating cost.
2. Fuel cost is more, since in India diesel is costly.
3. The plant cost per kW is comparatively more.
4. The life of diesel power plant is small due to high maintenance.
5. Noise is a serious problem in diesel power plant.
6. Diesel power plant cannot be constructed for large scale.

**Applications:**

1. They are quite suitable for mobile power generation and are widely used in transportation systems consisting of railroads, ships, automobiles and aeroplanes.
2. They can be used for electrical power generation in capacities from 100 to 5000 H.P.

3. They can be used as standby power plants.

4. They can be used as peak load plants for some other types of power plants.

5. Industrial concerns where power requirement are small say of the order of 500 kW, diesel power plants become more economical due to their higher overall efficiency.