Unit-I

COMPARISON BETWEEN SI AND CI ENGINES (GENERAL COMPARISON):

S. NO.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
1	It draws air fuel mixture into the cylinder during suction stroke	It draws only air into the cylinder during suction stroke.
2	Petrol engines operate with low pressure and temperature	Diesel engines operate with high pressure and temperature
3.	Pressure ranges from 6 to 12 bar Temperature ranges from 250°C to 300°C	Pressure ranges from 35 to 40 bar Temperature ranges from 600oC to 700oC
4	It is fitted with carburettor and spark plugs	It is fitted with fuel injection pump and injectors
5	The burning of fuel takes place at constant volume	The burning of fuel takes place at constant pressure
6.	Ignition of air fuel mixture takes place by an electric spark produced by spark plug	Ignition of air fuel takes placed by a injection of fuel into the hot compressed air.
7	Petrol engines are quality governed engines. The speed of petrol engines are controlled by varying the quantity of air fuel mixture.	Diesel engines are quantity governed engines. The speed of diesel engines is controlled by varying quality of air fuel mixture. (rich or weak mixture)
8	Petrol engines are widely used in automobiles and aeroplanes etc.,	Diesel engines are widely used in heavy vehicles, such as buses, lorries, trucks etc.,

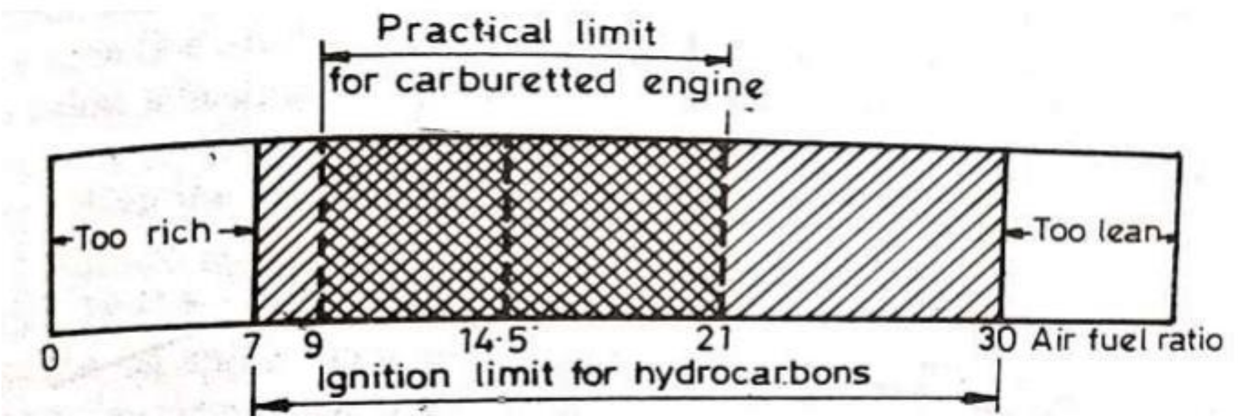
Difference Between 2 Stroke and 4 Stroke Engine

2 Stroke	4 Stroke
It can generate one revolution of the crankshaft within one power stroke, i.e.one power stroke per 360 degrees rotation of the crankshaft.	It can generate two revolutions of the crankshaft between one power stroke i.e., one power stroke in every 720 degrees rotation of the crankshaft.
Uses port for inlet and outlet of fuel.	Uses valve for inlet and outlet.
It requires a lighter flywheel to cause a more balanced force due to one revolution for one power stroke.	It requires heavy flywheel because it gives rise to unbalanced forces due to two revolutions for one power stroke.
Cheaper in price as they require less effort in manufacturing and are light by weight.	Hard to manufacture due to the heavy flywheel and valve mechanism and are expensive due to the valve and lubrication mechanism.
Generates more torque at a higher rpm.	Generates a higher torque at a lower rpm.
The charge is partially burnt and it gets mixed with the burnt gases during inlet.	The charge is fully burnt and doesn't get mixed with the gases inside the cylinder.
More power generation.	Less power generation.
Produces more heat so it requires greater cooling and lubrication.	Generates less heat.
Lower thermal efficiency	Higher thermal efficiency

Combustion in SI engines

Conditions necessary for combustion are:
• Presence of combustible mixture
• Some means of initiation combustion
• Stabilization and propagation of flame in the combustion chamber SI engine combustible mixture supplied by carburettor and combustion initiated by an electric spark

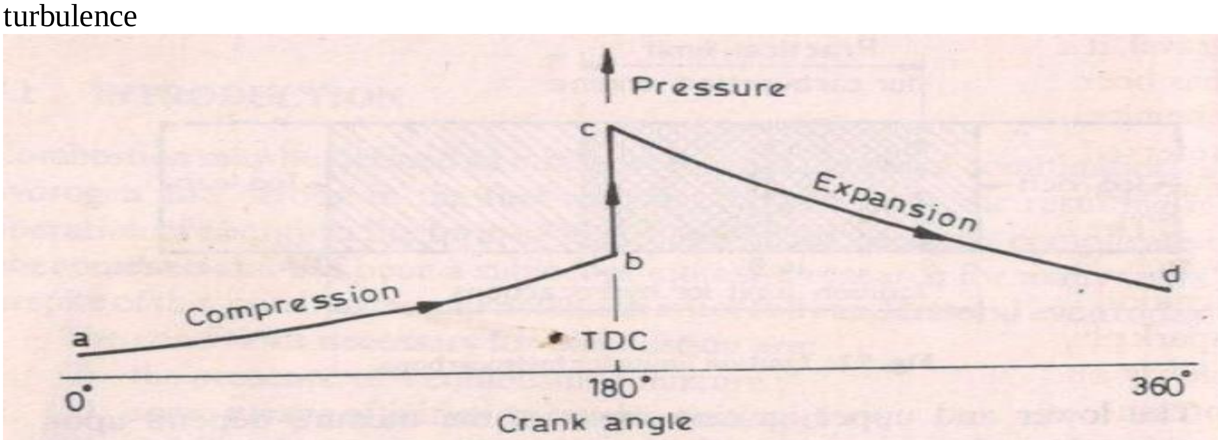
Ignition Limit:
Flame will propagate if temperature of burnt gases exceeds approx. 1500 K Relative fuel-air ratio lie between 0.5 and 2.1 Stoichiometric mixture is 1:15 Fuel-air must be between 1:30 and 1:7



Upper and lower limit depend upon mixture ratio and temperature. Ignition limits are wider at increased temperatures because of higher rates of reaction and higher thermal diffusivity coefficients of mixture.

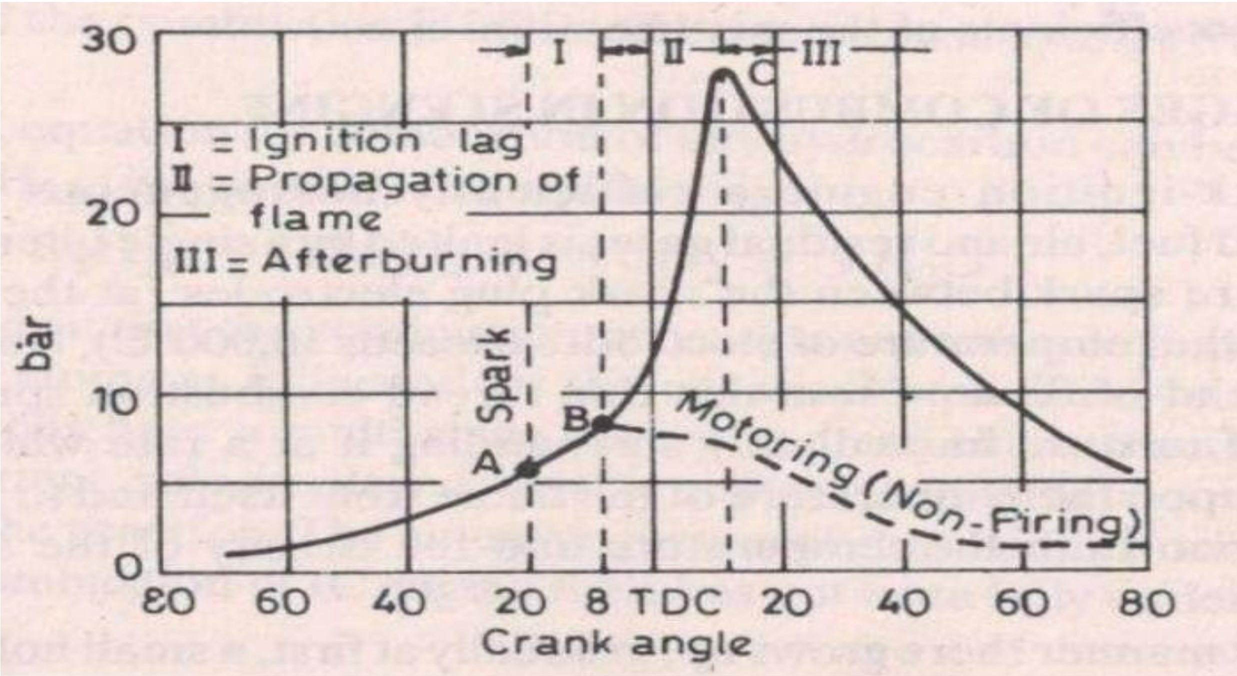
1.Stages of combustion in SI engine: -

homogeneous mixtures of vapourised fuel, air and residual gases -electrodes temp. exceeds 10,000°C -manner of a soap bubble -flame front travel dependent primarily on the degree of turbulence



Theoretical p-θ diagram

1) Ignition lag or preparation phase (AB): -growth and development of a semi propagating nucleus of flame -chemical process depending upon the nature of the fuel, upon both temperature and pressure, the proportion of the exhaust gas, and also upon the temperature coefficient of the fuel, that is, the relationship of oxidation or burning -point A shows the passage of spark and point B is the first rise of pressure -ignition lag is generally expressed in terms of crank angle -Ignition lag is very small and lies between 0.00015 to 0.0002 seconds -ignition lag of 0.002 seconds corresponds to 35 deg crank rotation when the engine is running at 3000 RPM -Angle of advance increase with the speed



Stages of combustion in SI engine

2) propagation of flame (BC): -Period from the point B where the line of combustion departs from the compression line to point C, the maximum rise of pressure in P-θ diagram -flame propagates at the constant velocity -Heat transfer to the cylinder wall is low -rate of heat release depends upon the turbulence intensity and reaction rate

3) After burning (CD): -After point C, the heat release is due to the fuel injection in reduced flame front after the starts of expansion stroke -no pressure rise during this period

2.EFFECT OF ENGINE VARIABLES ON IGNITION LAG

Ignition lag in terms of crank angle is 10^o to 20^o and in terms of seconds, 0.0015 second or so. Duration depends on the following factors: Fuel: Chemical nature of fuel High self-ignition temperature of fuel longer the ignition lag.

Initial temperature and pressure:

rate of reaction depends on increasing the intake temperature and pressure, increasing the compression ratio, chemical reaction rate and retarding the spark all reduce the ignition lag

Electrode gap: lower the compression ratio and higher the electrode gap is desirable -voltage required at the spark plug electrode to produce spark is found to increase with decrease in fuel-air ratio and with increase in compression ratio and engine load

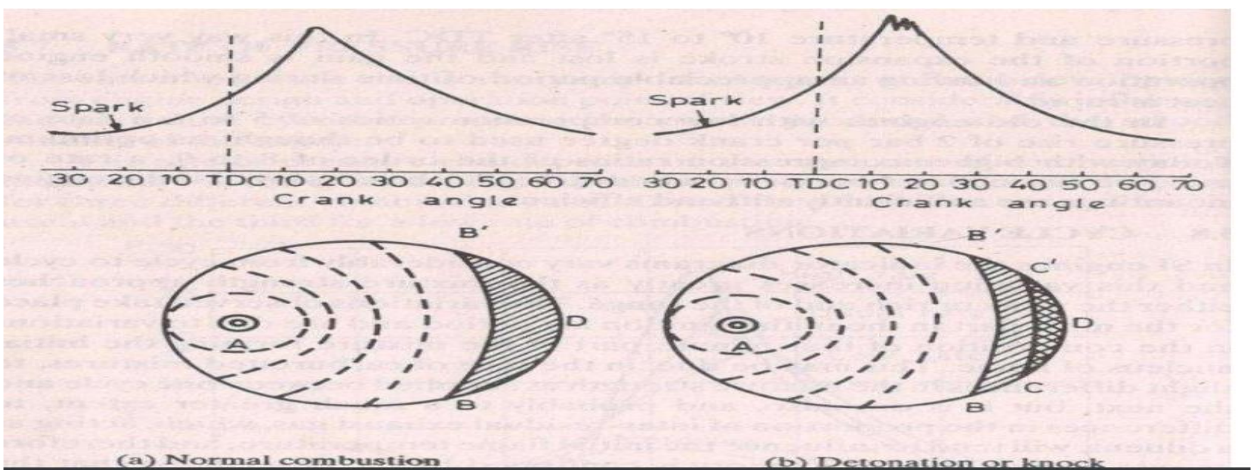
Turbulence: directly proportional to engine speed -engine speed does not affect much ignition lag measured in milliseconds -but ignition lag increases linearly with engine speed when measured in degree crank angle -spark advance is desirable in higher engine speed -Excessive turbulence of the mixture in the area of spark plug is harmful

The factors which affect the flame propagations are
Fuel-ratio

I. Compression ratio
II. Intake temp. and press.
III. Load on engine
IV. Turbulence and engine speedϖ Engine Size

3.ABNORMAL COMBUSTION -Occurs due to engine operating conditions - Variety of ways in which abnormal combustion can occur such as “detonation or knock”, “preignition”, “run-on” etc

Detonation or knocking - Normal flame front travels at 15 to 30 m/s speed - Temperature increases due to flame front advance, radiation and reactions of unburnt mixture - During abnormal combustion end charge auto-ignites before the flame front reaches - Velocities reached during detonation are 300 to 1000 m/s - Press rise almost 3 to 4 times i.e. 50 bar to 150-200 bar - This pressure frequency or vibration frequency in SI engine can be up to 5000 Cycles per second. Denotation is undesirable as it affects the engine performance and life, as it abruptly increases sudden large amount of heat energy. It also put a limit on compression ratio at which engine can be operated which directly affects the engine efficiency and output.



(a) Normal combustion (b) Detonation or knock

***Auto ignition** A mixture of fuel and air can react spontaneously and produce heat by chemical reaction in the absence of flame to initiate the combustion or self-ignition. This type of self-ignition in the absence of flame is known as Auto-Ignition. The temperature at which the self-ignition takes place is known as self-igniting temperature. The pressure and temperature abruptly increase due to auto-ignition because of sudden release of chemical energy. This auto-ignition leads to abnormal combustion known as detonation which is undesirable because its bad effect on the engine performance and life as it abruptly increases sudden large amount of heat energy. In addition to this knocking puts a limit on the compression ratio at which an engine can be operated which directly affects the engine efficiency and output.

***Pre-ignition** Pre-ignition is the ignition of the homogeneous mixture of charge as it comes in contact with hot surfaces, in the absence of spark. Auto ignition may overheat the spark plug and exhaust valve and it remains so hot that its temperature is sufficient to ignite the charge in next cycle during the compression stroke before spark occurs and this causes the pre-ignition of the charge. Pre-ignition is initiated by some overheated projecting part such as the sparking plug electrodes, exhaust valve head, metal corners in the combustion chamber, carbon deposits or protruding cylinder head gasket rim etc. pre-ignition is also caused by persistent detonating pressure shockwaves scoring away the stagnant gases which normally protect the combustion chamber walls. The resulting increased heat flow through the walls, raises the surface temperature of any protruding poorly cooled part of the chamber, and this therefore provides a focal point for pre-ignition.

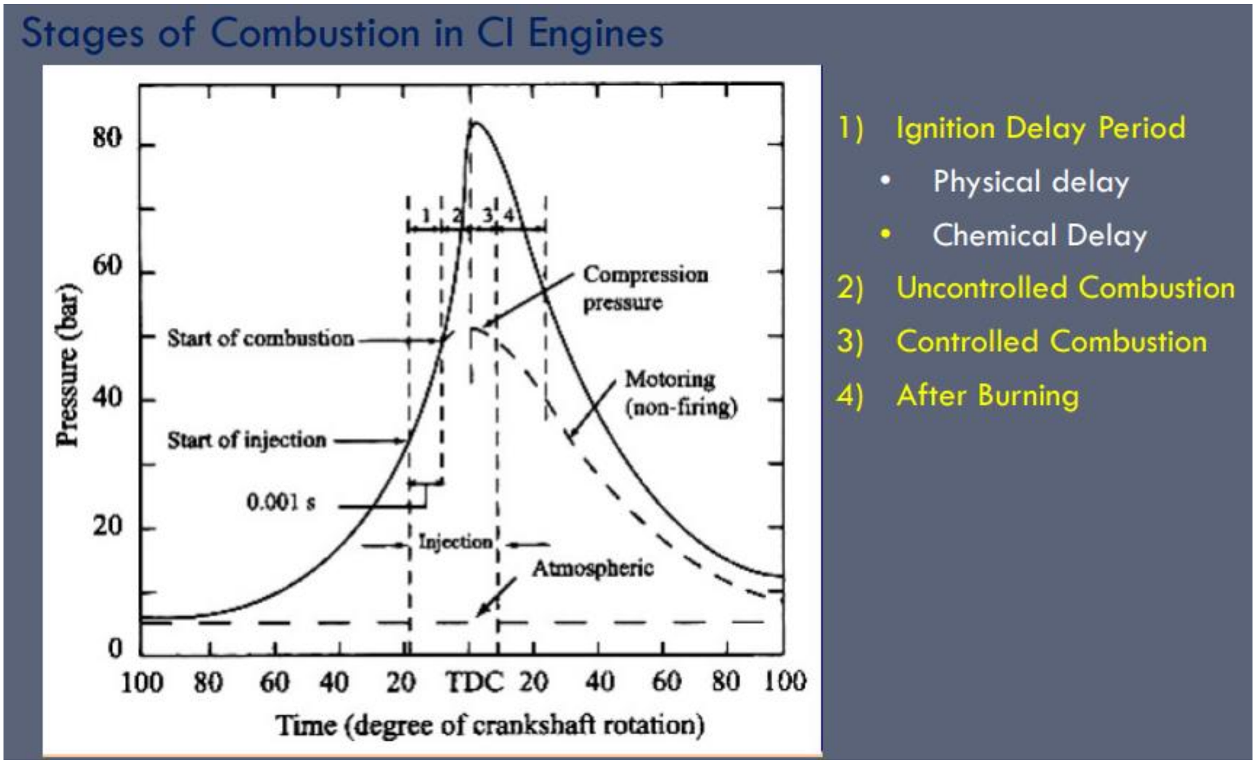
Combustion in CI Engines

• Combustion in CI engines differ from SI engine due to the basic fact that CI engine combustion is unassisted combustion occurring on its' own.
• In CI engine the fuel is injected into combustion space after the compression of air is completed. • Due to excessively high temperature and pressure of air the fuel when injected in atomised form gets burnt on its' own and burning of fuel is continued till the fuel is injected. • Theoretically this injection of fuel and its' burning should occur simultaneously up to the cut-off point, but this does not occur in actual CI engine. Different significant phases of combustion are explained as under.

4.Stages of Combustion in CI Engines

(i) Ignition Delay Period

Injection of fuel in atomized form is initiated into the combustion space containing compressed air.
• Fuel upon injection does not get burnt immediately instead some time is required for preparation before start of combustion.
• Fuel droplet injected into high temperature air first gets transformed into vapour (gaseous form) .
• Subsequently, if temperature inside is greater than self ignition temperature at respective pressure then ignition gets set.
• Thus, the delay in start of ignition may be said to occur due to 'physical delay' i.e. time consumed in transformation from liquid droplet into gaseous form, and'chemical delay' i.e. time consumed in preparation for setting up of chemical reaction (combustion).



Uncontrolled Combustion

During the ignition delay period also the injection of fuel is continued as it has begun at point ‘a’ and shall continue upto the point of cut-off.

• For the duration in which preparation for ignition is made, the continuous fuel injection results in accumulation of fuel in combustion space.

• The moment when ignition just begins, if the sustainable flame front is established then this accumulated fuel also gets burnt rapidly.

• This burning of accumulated fuel occurs in such a manner that combustion process becomes uncontrolled resulting into steep pressure rise as shown from ‘b’ to ‘c’.

• The uncontrolled burning continues till the collected fuel gets burnt.

• During this ‘uncontrolled combustion’ phase if the pressure rise is very abrupt then combustion is termed as ‘abnormal combustion’ and may even lead to damage of engine parts in extreme conditions

Controlled Combustion

• After the ‘uncontrolled combustion’ is over then the rate of burning matches with rate of fuel injection and the combustion is termed as ‘controlled combustion’.

• Controlled combustion is shown between ‘c’ to ‘d’ and during this phase maximum of heat gets evolved in controlled manner.

• In controlled combustion phase rate of combustion can be directly regulated by the rate of fuel injection i.e. through fuel injector.

• Controlled combustion phase has smooth pressure variation and maximum temperature is attained during this period.

• It is seen that about two-third of total fuel heat is released during this phase.

Abnormal Combustion

Thus, it is seen that the complete combustion in CI engines may be comprising of four distinct phases i.e. 'ignition delay' followed by 'uncontrolled combustion,' 'controlled combustion' and 'after burning'.

• Combustion generally becomes abnormal combustion in CI engines when the ignition delay is too large resulting into large uncontrolled combustion and zig-zag pressure rise.

• Abnormal combustion in CI engines may also be termed as 'knocking' in engines and can be felt by excessive vibrations, excessive noise, excessive heat release, pitting of cylinder head and piston head etc.

• In order to control the knocking some additives are put in CI engine fuel so as to reduce its' self ignition temperature and accelerate ignition process.

• Also, the combustion chambers are properly designed so as to have reduced physical and chemical delay.

5.Factors affecting Delay Period in CI Engines

Compression Ratio Increase in CR increases the temperature of air. Autoignition temperature decreases with increased density. Both these reduce the delay period(DP).

• **Engine Power** Output With an Increase in engine power, the operating temperature increases. A/F ratio decreases and delay period decreases

• **Engine Speed** Delay period decreases with increasing engine speed, as the temperature and pressure of compressed air rises at high engine speeds.

• **Injection Timing** The temperature and pressure of air at the beginning of injection are lower for higher injection advance. The DP increases with increase in injection advance or longer injection timing. The optimum angle of injection is 20° BTDC

• **Atomization of fuel** Higher fuel injection pressures increase the degree of atomization. The fineness of atomization reduces the DP due to higher A/V ratio of the spray droplets.

Comparison of Knocking in SI and CI Engines

Parameter	SI Engines	CI Engines
Timing	Occurs at the end of combustion	Occurs at the beginning of combustion
Major Cause	Auto ignition of end charge	Ignition of accumulated fresh charge
Pre-Ignition	Possible as the fuel air mixture is compressed	Not possible as only air is compressed

Parameters which reduce knocking in SI and CI Engines

S.No.	Parameter	SI Engines	CI Engines
1	Self Ignition Temperature of fuel	High	Low
2	Ignition Delay	Long	Short
3	Inlet Temperature	Low	High
4	Inlet Pressure	Low	High
5	Compression Ratio	Low	High
6	Speed	Low	High
7	Combustion Chamber Wall Temperature	Low	High
8	Cylinder Size	Small	Large

UNIT-II

Classify air compressors

Classification of Air compressors:

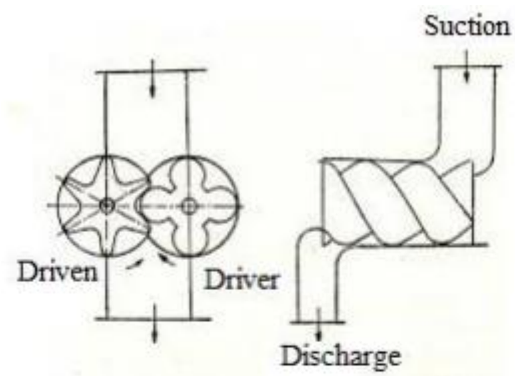
1. According to principle: a) Reciprocating air compressors b) Rotary air compressors

2. According to the capacity a. Low capacity air compressors b. Medium capacity air compressors c. High capacity air compressors

3. According to pressure limits a. Low pressure air compressors b. Medium pressure air compressors c. High pressure air compressors 4. According to method of connection a. Direct drive air compressors b. Belt drive air compressors c. Chain drive air compressors

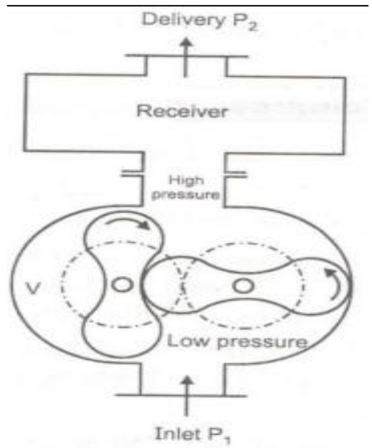
1.Explain with sketch working of screw compressor.

A rotary-screw compressor is a type of gas compressor that uses a rotary-type positivedisplacement mechanism. They are commonly used to replace piston compressors where large volumes of high-pressure air are needed, either for large industrial applications or to operate highpower air tools. Rotary-screw compressors use two meshing helical screws, known as rotors, to compress the gas. In a dry-running rotary-screw compressor, timing gears ensure that the male and female rotors maintain precise alignment. In an oil-flooded rotary-screw compressor, lubricating oil bridges the space between the rotors, both providing a hydraulic seal and transferring mechanical energy between the driving and driven rotor. Gas enters at the suction side and moves through the threadsas the screws rotate. The meshing rotors force the gas through the compressor, and the gas exits at the end of the screws.

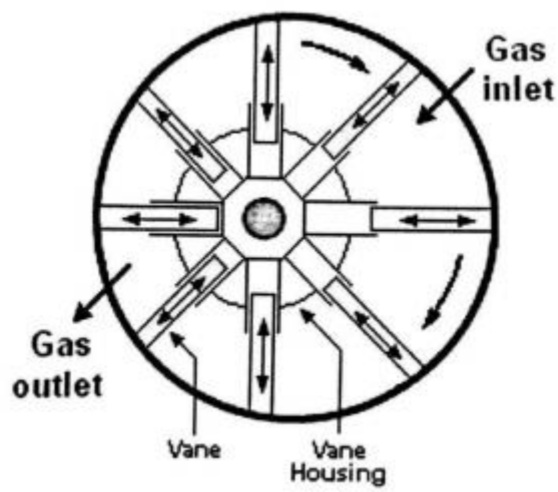


2.Explain with neat sketch working of lobe type air compressor.

Lobe type air compressor: it is a rotary type of compressor consisting of two rotors which are driven externally. One rotor is connected to drive and second is connected to gear. These two rotors have two or three lobes having epicycloids, hypocycloid or involutes profiles. In the figure two lobes compressor is shown with a inlet arrangement and receiver. A very small clearance is maintained between surfaces so that wear is prevented. Air leakage through this clearance decreases efficiency of this compressor. During rotation a volume of air V at atmospheric pressure is trapped between left hand rotor and casing . this air is positively displaced with change in volume until space is opened to high pressure region. At this instant some high pressure air rushes back from the receiver and mixed with the blower air until both pressure are equalized .

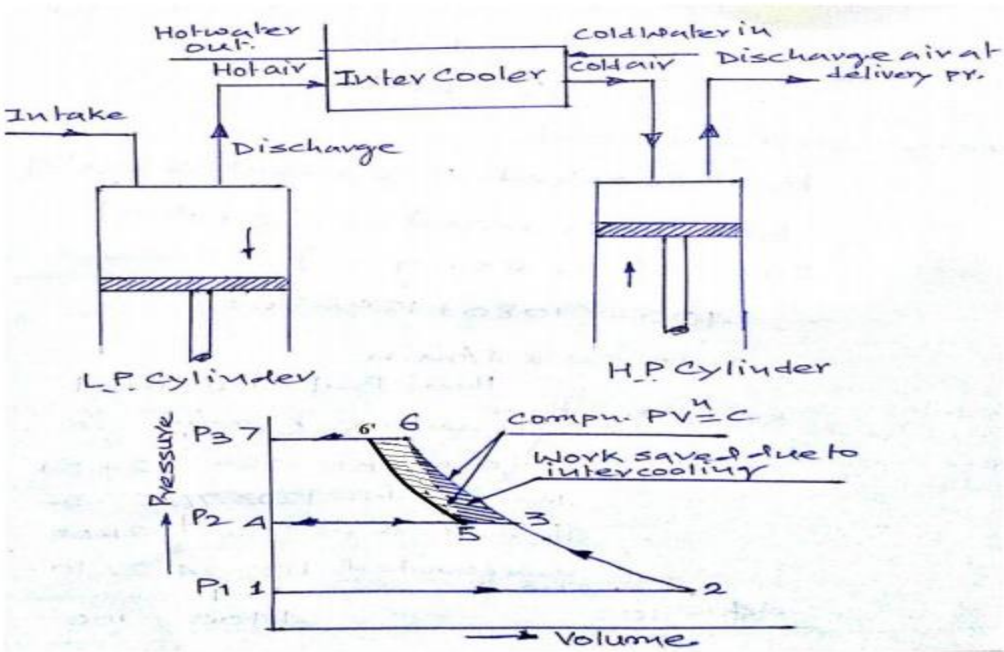


3.Draw a neat sketch of vane compressor and label the different parts.



4.What is the necessity of multistage compression ? Explain the working of two stage reciprocating air compressor with intercooler, with the help of p-v diagram.

Necessity of multistage compression i) As index of compression 'n' increases it increases compression work. ii) Increase in pressure ratio (P2/P1) it increases work as well as size of cylinder. iii) Increment in pressure ratio (P2/P1) beyond certain limit, volumetric efficiency decreases while it increases leakage loss on either sides the piston and valves. Due to above pointes and for higher pressure ratio compressor needs multistaging.



5.Explain the working of two stage reciprocating compressor. Show work saved on PV diagram.

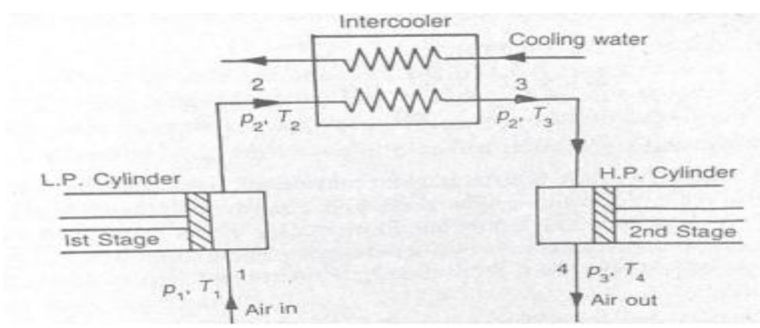
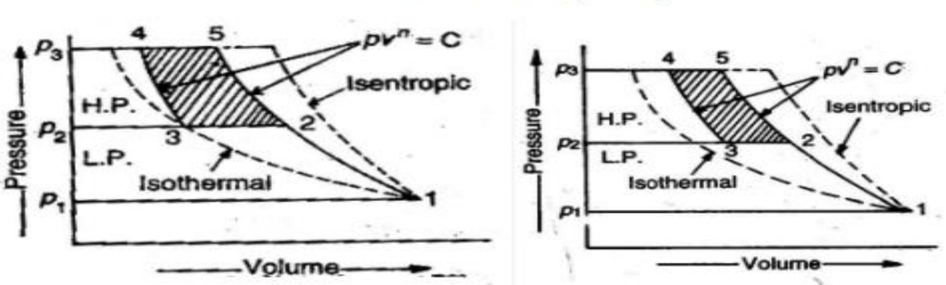


Fig.Two stage reciprocating air compressor……………………………………………..2M

Working:- Let P1, V1 be the pressure and volume of air entering the low pressure cylinder P2, V2 be the pressure and volume of air leaving the low pressure cylinder or pressure and volume of air entering the intercooler P3, V3 be the pressure and volume of air entering the high pressure cylinder P4, V4 be the pressure and volume of air leaving the stage and 'n' be the index of compression(As suitable). ………………………………………………..2M

Work saved=Area(2-3-4-5)



Perfect Intercooling

Imperfect Intercooling

………2M

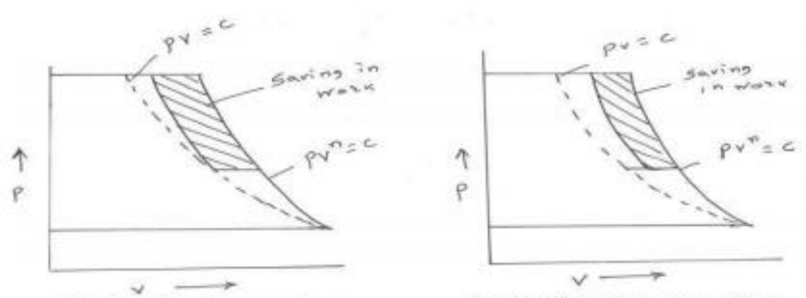
6.Differentiate between reciprocating and rotary compressors

Reciprocating compressor	Rotary compressor
1. Compressor of air take place with help of piston and cylinder arrangement with reciprocating motion of piston.	1. Compression of air take place due to rotary motion of blades.
2. Delivery of air intermittent.	2. Delivery of air is continuous.
3. Delivery pressure is high i.e. pressure ratio is high.	3. Delivery pressure is low, i.e. pressure ratio is low.
4. Flow rate of air is low.	4. Flow rate of air is high.
5. Speed of compressor is low because of unbalanced forces.	5. Speed of compressor is high because of perfect balancing.
6. Reciprocating air compressor has more number of moving parts.	6. Rotary air compressor has less number of moving part.
7. It needs proper lubrication and more maintenance.	7. It required less lubrication and maintenance.
8. Due to low speed of ration it can't be directly coupled to prime mover but it requires reduction of speed.	8. Rotary air compressor can be directly coupled to prime mover.
9. It is used when small quantity of air at high pressure is required.	9. It is used where large quantity of air at lower pressure is required.

7.Define perfect and imperfect inter-cooling in air compressor and show it by graph also

Perfect cooling: In this process the temperature of air after passing out of intercooler is same as that of temperature of air before compression in LP cylinder. The respective figure is shown.

Imperfect cooling: In this process the temperature of air after passing out of intercooler is between the temperature of air before & after compression in LP cylinder. The respective figure is shown.

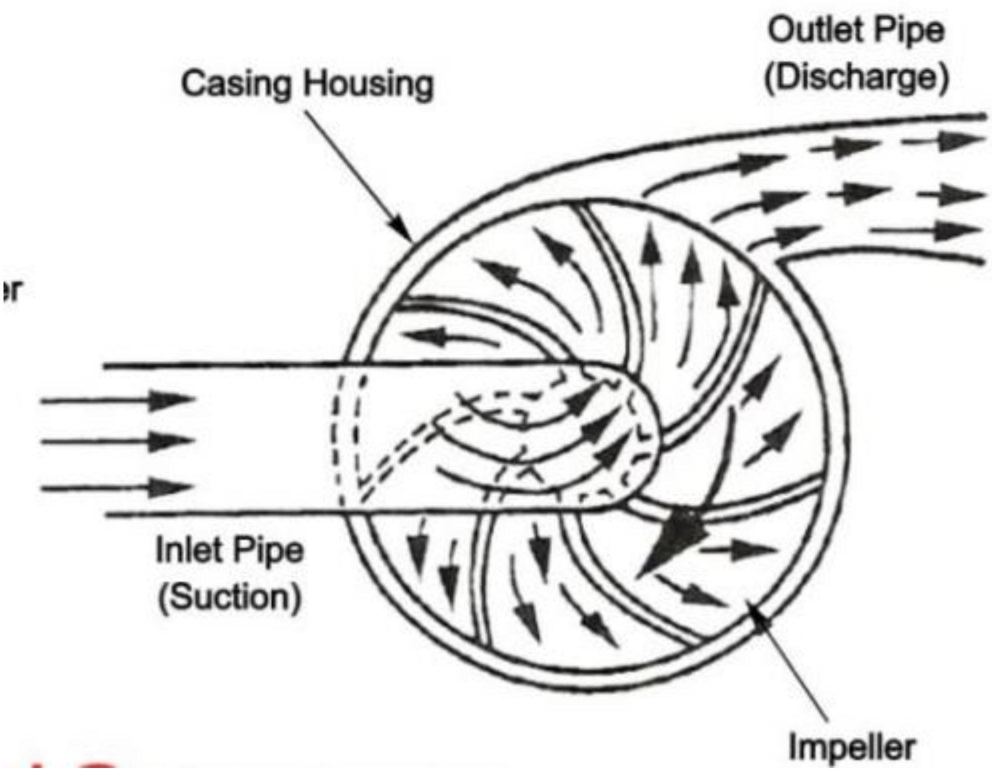


Perfect Intercooling Imperfect Intercooling

8.Working of Centrifugal Compressor

- After the start-up, gas or air is introduced from the air tank or any other source into the centrifugal compressor.
- After entering the compressor, the air strikes the impeller, which contains multiple radial blades rotating with the rotation of the impeller.

- As the air strikes the impeller blades, the air pushes to the centre of the impeller by centrifugal force.
- The impeller blades, after striking of air provide kinetic energy to the air which increases the velocity of the air.
- The air enters into the diffuser area after passing through the impeller. This diffuser contains multiple stationary vanes. As soon as the air enters the diffuser area, its speed or velocity of flow of the air starts to decrease.
- Now, according to Bernoulli's principle, the velocity square is inversely proportional to pressure. The diffuser converts this increased velocity of the air into pressure energy before the air is drawn into the centre of impeller. This increase in the impeller's pressure under most conditions will be roughly equal to the increase in diffuser pressure.



9.Working of an Axial Flow Compressor:

The basic working principle behind an axial flow compressor is that the rotor imparts kinetic energy to the gas. This kinetic energy is later converted to static pressure when it is diffused through passages or when it strikes on the rotor.

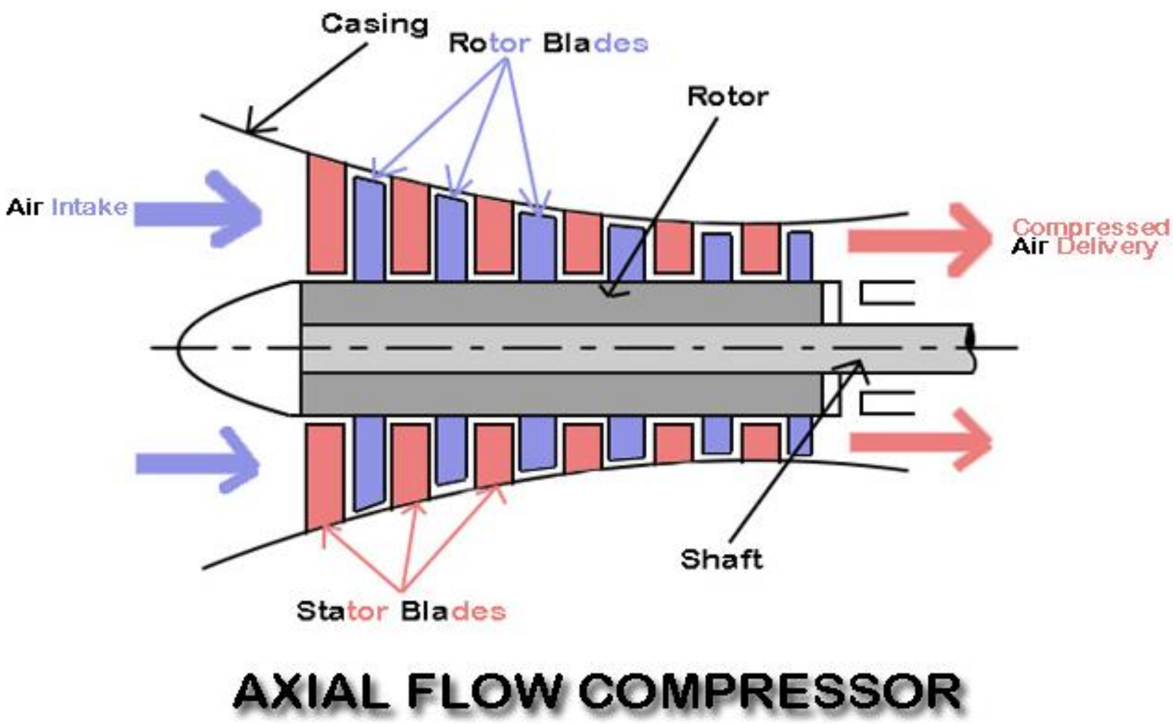
For an axial flow compressor, the flow of gases is along the axis.

At the start, inlet guide vanes or stator blades are present. It is to ensure that the gases strike on the rotor with the proper angle of attack. And the rotor is placed next to the stator blade. The aerofoil shape of the blade is a crucial feature for this action.

Axial Flow Compressor works in many stages. A rotor and a stator together constitute one. Generally, there can be five to fifteen stages in an axial flow compressor. The number of stages is determined by the pressure ratio that needs to attain as well as the amount of gas.

The stator and rotor blades are alternately packed. Gases first collide on the stator or the first guide vane. It guides the gases to the rotating rotor blade that follows next.

The rotor blades then increase the kinetic energy of the gases and supply it to the adjacent stator blade.

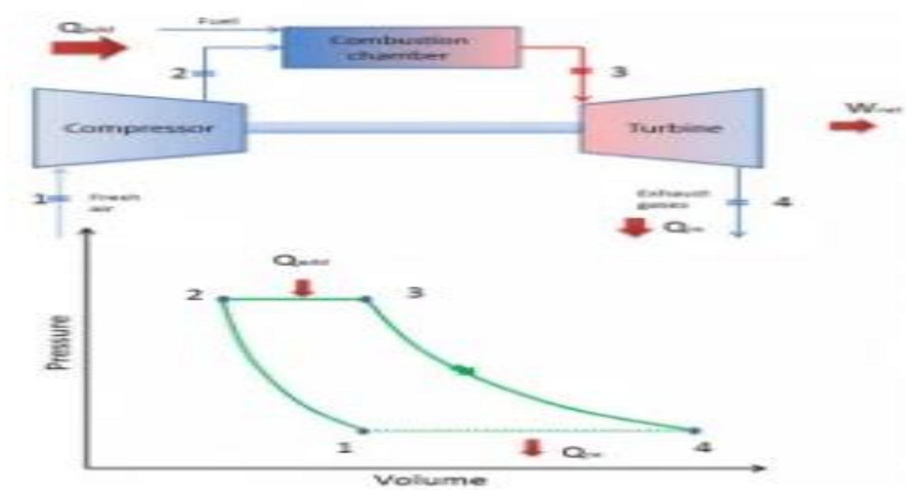


S.no	Centrifugal Compressors	Axial Flow Compressors
1	In centrifugal compressors air flows radially in the compressor	In Axial flow compressors air flows parallel to the axis of shaft
2	Low maintenance and running cost	High maintenance and running cost
3	Low starting torque is required	Requires high starting torque
4	Not suitable for multi staging	Suitable for multi staging
5	Suitable for low pressure ratios up to 4	Suitable for only multi staging ratio of 10
6	For given mass flow rate, it requires a larger frontal area.	For a given mass flow rate, it requires less Frontal area.
7	Isentropic efficiency is 80 to 82%	Isentropic efficiency is 86 to 88%
8	Better performance at part load	Poor performance at part load

UNIT-III

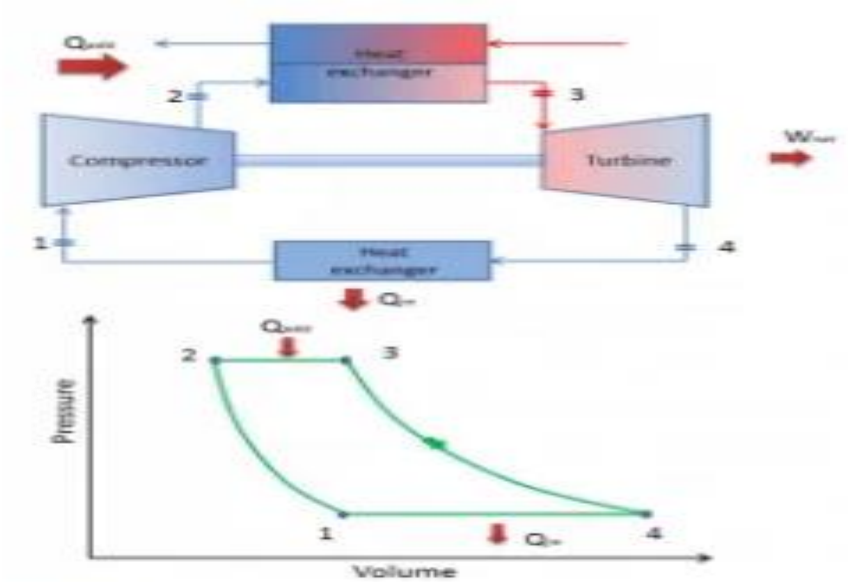
Types of Brayton Cycle

1.Types of Brayton Cycle
Open Brayton Cycle (keywords)
Since most gas turbines are based on the **Brayton cycle** with **internal combustion** (e.g.,, jet engines), they are based on the **open Brayton cycle**. In this cycle, air from the ambient atmosphere is compressed to the compressor’s higher pressure and temperature. In the combustion chamber, the air is heated further by burning the fuel-air mixture in the airflow. Combustion products and gases expand in the turbine either to near atmospheric pressure (engines producing mechanical energy or electrical energy) or to a pressure required by the jet engines. The open Brayton cycle means that the gases are discharged **directly into the atmosphere**.



open Brayton cycle

Closed Brayton Cycle
In a **closed Brayton cycle,** the working medium (e.g.,, helium) **recirculates in the loop,** and the gas expelled from the turbine is reintroduced into the compressor. A **heat exchanger** (external combustion) is usually used in these turbines, and only a clean medium with no combustion products travels through the power turbine. The **closed Brayton cycle** is used, for example, in closed-cycle gas turbines and high-temperature gas-cooled reactors.



closed Brayton cycle

2.Types of Jet Engines

Following are the main types of jet engines, which are described below:

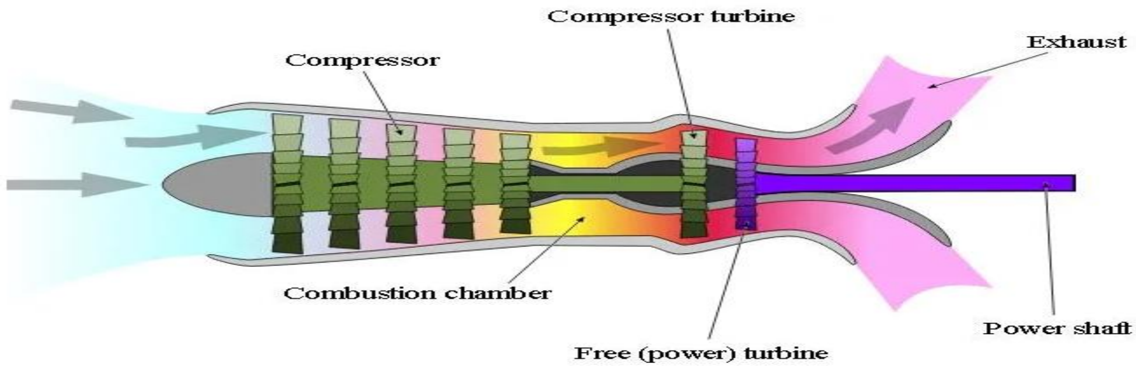
1. Turboshaft engine
2. Turboprop engine
3. Turbofan engine
4. Turbo Jet Engine
5. Ram Jet Engine
6. Rocket Motor

1. Turboshaft Engine

A turboshaft engine is a type of gas-powered turbine that works similarly to a turboprop engine. Turboshaft engines do not drive propellers. It is used in helicopters to power the rotor.

The difference between turboshaft and turbojet is that turboshaft engines use most of their power to turn the turbine, not to generate thrust from the rear of the engine. These are turbojet engines with a large shaft attached to the rear.

1. Turboshaft Engine



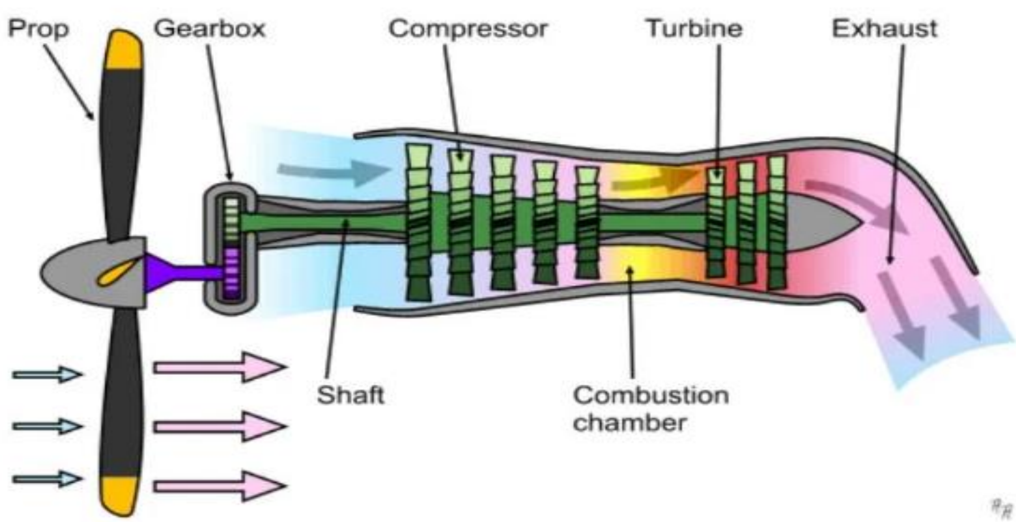
2. Turboprop Engine

The first turboprop engine was built in Budapest in 1938. It is a type of jet engine that uses a gearing system to connect to an aircraft propeller. Turboprop aircraft engines save fuel and spin at medium-range speeds.

Turboprop engines are good at mid-range altitude, but their weight is likely to damage the gearing system. A turboprop engine consists of a combustion chamber, containing pressurized air and gas, a turbine, and a compressor.

Although, modern turboprop engines have smaller propeller diameters. These engines have multiple blades that help stabilize the aircraft at altitude. Like a turbofan aircraft engine, a turboprop engine converts gas stream energy into mechanical power to achieve its propulsion.
This propeller generates power to drive the load, accessories, and compressor. Such jet engines come with shafts attached to the turbines that drive the propellers through a reduction gear system.

2. Turboprop Engine

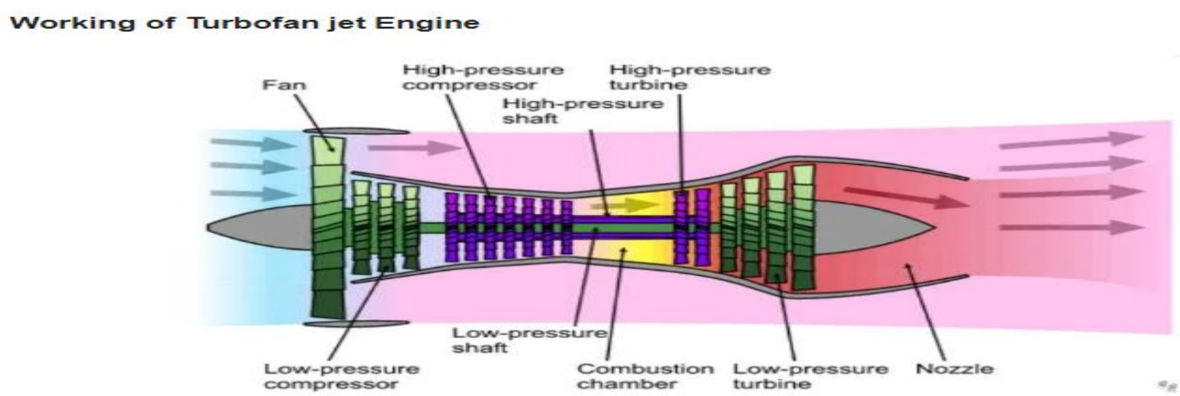


3. Turbofan Engine

These engines have a large fan at the front to suck in the air. Towards turbofan jet engines, most of the air flows around the aircraft engine allowing the aircraft to fly more loudly or quietly, even at low speeds.

The turbofan aircraft engine is an improved version of the turboprop and turbojet engine. It works like a turbojet engine but with a ducted fan mounted at the front. This has the advantage that the engine cools down, producing additional thrust and reducing aircraft engine noise.

Working of Turbofan jet Engine



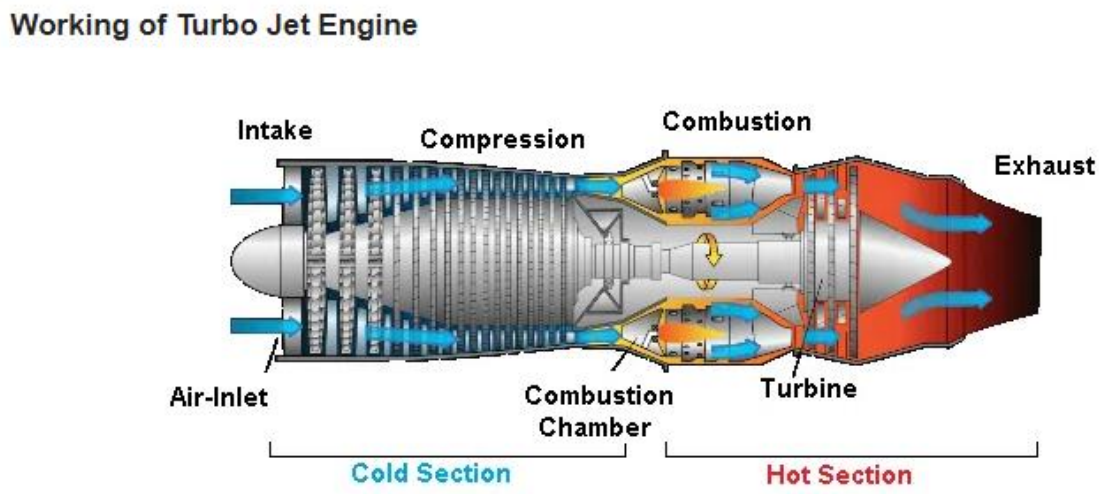
4. Turbo Jet Engine

These types of jet engines take their oxygen supply from the surrounding atmosphere. The turbojet engine contains a diffuser at the front end, an expansion nozzle (also called propelling nozzle) at the rear end. The energy produced consists of a combustion chamber, a fuel pump, a gas turbine, and an air compressor.

The air is compressed into the chamber, it is heated, and expanded by the fuel combustion. It is then allowed to expand through a turbine into a nozzle, where it is accelerated to high speed to provide propulsion.

Atmospheric air enters the diffuser with the same velocity as the propulsion unit. The function of a diffuser is to convert the kinetic energy of entering air into its pressure energy. The high-pressure air now enters the compressor, where its pressure is increased and the temperature rises accordingly.

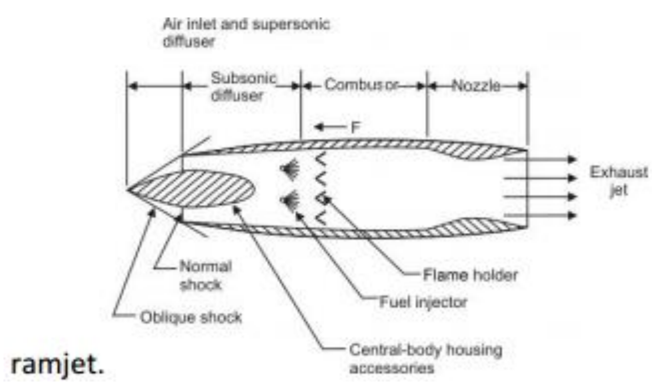
The high pressure and temperature compressed air now enter the spherical combustion chamber in which the liquid fuel is injected through a ring through a pump. In the combustion chamber, the fuel burns at constant pressure by coming in contact with hot compressed air.



3.Explain with neat sketch working principle of Ram jet engine

Answer:
Ramjet has no compressor as the entire compression depends upon compression. Function of supersonic & subsonic difference to convert the kinetic called the ram pressure.

Working:- The air entering into ram jet with supersonic speed is slowed down to sonic velocity in the supersonic diffuser ,increasing air pressure. The air pressure is further increase in the subsonic diffuser increasing also the temperature of air. The diffuser section is designed to get correct ram effect. it's job is to decrease the velocity & increase pressure of incoming air. The fuel injected into combustion chamber is burned with help of flame igniter. The high pressure and high temperature gases are passed through the nozzle converting into pressure energy into kinetic energy. The high velocity gas leaving the nozzle provide required toward thrust to.



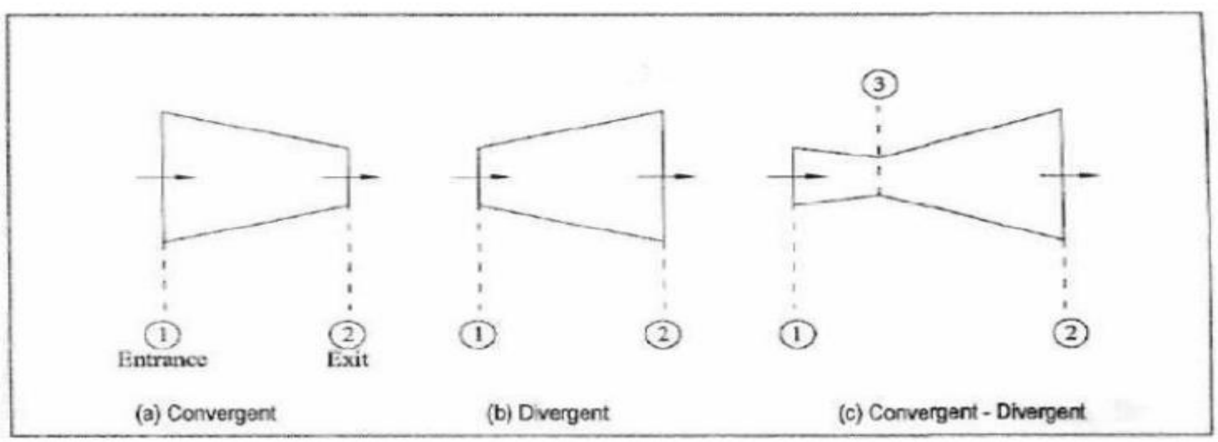
UNIT-4

STEAM NOZZLES In steam turbines, the overall transformation of heat energy of steam into mechanical work takes place in two stages:- 1) Available steam energy into kinetic energy 2) Kinetic energy into mechanical work. The first stage is accomplished with the devices called steam nozzles.

A steam nozzle is a duct or passage of smoothly varying cross sectional area which converts heat energy of steam into kinetic energy. The shape of the nozzle is designed such that it will perform this conversion of energy with minimum loss.

Applications of Nozzles 1) Steam and Gas turbines, 2) Jet engines, 3) For propulsion of rocket motors, 4) Flow measurements, 5) In injectors for pumping water , 6) In ejectors for removing air from condensers .

1.Types of Steam Nozzles Three important types of steam nozzles are:- 1) Convergent Nozzle, 2) Divergent Nozzle, 3) Convergent-Divergent Nozzle.



CLASSIFICATION OF STEAM TURBINE Classification of steam turbines may be done as following:

1. According to action of steam (a) Impulse turbine (b) Reaction turbine (c) Combination of both

2. According to direction of flow: (a) Axial flow turbine (b) Radial flow turbine

3. According to number of stages (a)Single stage turbine (b)Multi stage turbine

4 .According to steam pressure at inlet of Turbine: (a) Low pressure turbine (b) Medium pressure turbine. (c) High pressure turbine (d) Super critical pressure turbine.

5.According to method of governing: (a) Throttle governing turbine. (b) Nozzle governing turbine. (c) By pass governing turbine.

6. According to usage in industry: (a) Stationary turbine with constant speed. (b) Stationary turbine with variable speed. (c) Non stationary turbines.

Description of common types of Turbines The common types of steam turbine are

1. Impulse Turbine.

2. Reaction Turbine. The main difference between these two turbines lies in the way of expanding the steam while it moves through them.

Simple impulse Turbine In the impulse turbine, the steam is expanded within the nozzle and there is no any change in the steam pressure as it passes over the blades.

Reaction Turbine

In this type of turbine, there is a gradual pressure drop and takes place continuously over the fixed and moving blades. The rotation of the shaft and drum, which carrying the blades is the result of both impulse and reactive force in the steam. The reaction turbine consist of a row of stationary blades and the following row of moving blades. The fixed blades act as a nozzle which are attached inside the cylinder and the moving blades are fixed with the rotor.

Compounding in Steam Turbine

The compounding is the way of reducing the wheel or rotor speed of the turbine to optimum value. It may be defined as the process of arranging the expansion of steam or the utilization of kinetic energy or both in several rings. There are several methods of reducing the speed of rotor to lower value. All these methods utilize a multiple system of rotors in series keyed on a common shaft, and the steam pressure or jet velocity is absorbed in stages as the steam flow over the blades.

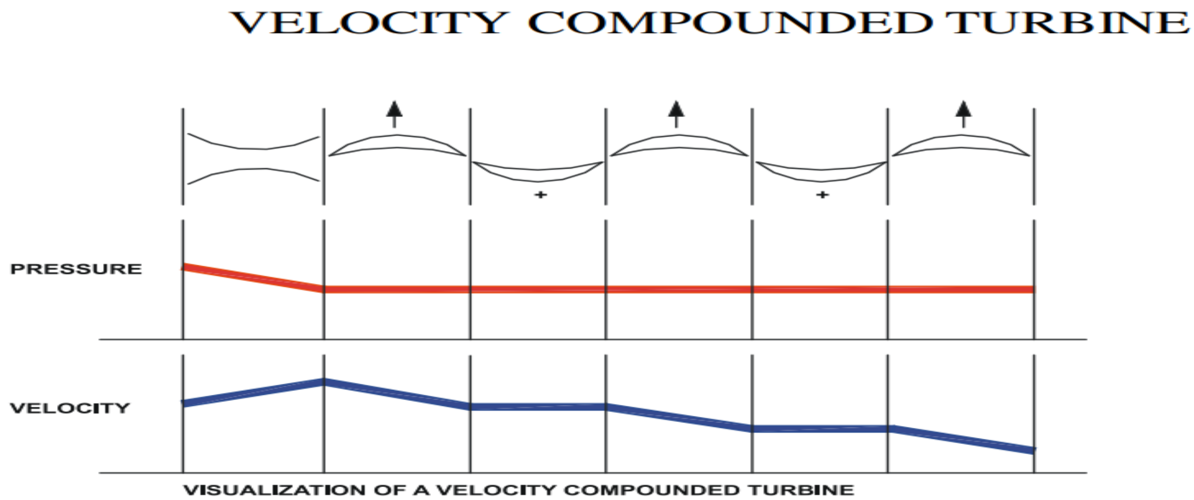
2. Different methods of compounding are:

1.Velocity Compounding

2.Pressure Compounding 3.Pressure Velocity Compounding

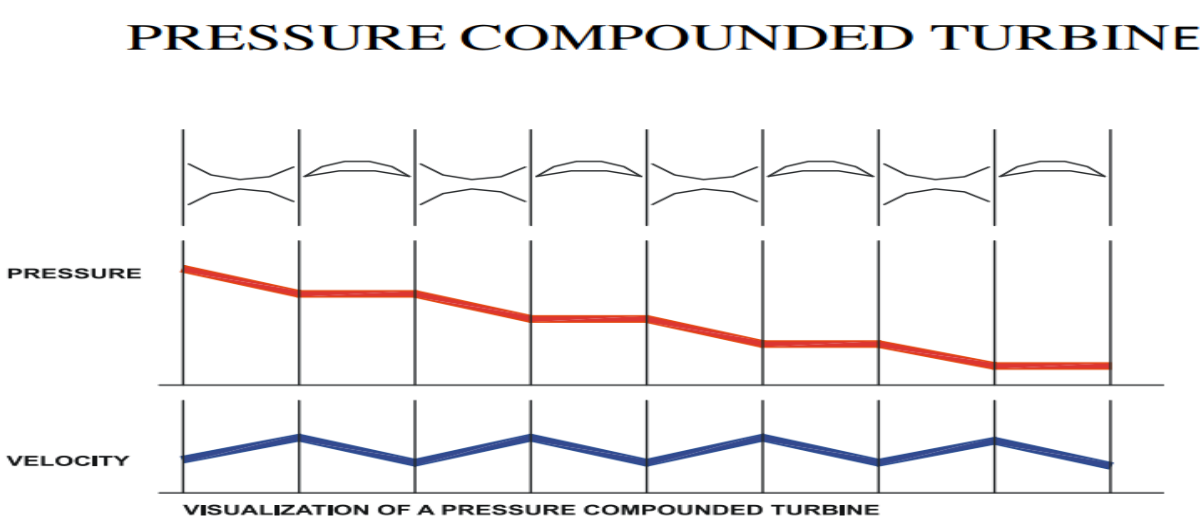
Velocity Compounding There are number of moving blades separated by rings of fixed blades. All the moving blades are keyed on a common shaft. When the steam passed through the nozzles where it is expanded to condenser pressure. It's Velocity becomes very high. This high velocity steam then passes through a series of moving and fixed blades.

When the steam passes over the moving blades it's velocity decreases. The function of the fixed blades is to re-direct the steam flow without altering it's velocity to the following next row moving blades where a work is done on them and steam leaves the turbine with allow velocity as shown in diagram



Pressure Compounding

There are the rings of moving blades which are keyed on a same shaft in series, are separated by the rings of fixed nozzles. The steam at boiler pressure enters the first set of nozzles and expanded partially. The kinetic energy of the steam thus obtained is absorbed by moving blades. The steam is then expanded partially in second set of nozzles where it's pressure again falls and the velocity increase the kinetic energy so obtained is absorbed by second ring of moving blades. This process repeats again and again and at last, steam leaves the turbine at low velocity and pressure. During entire process, the pressure decrease continuously but the velocity fluctuate as shown in diagram.

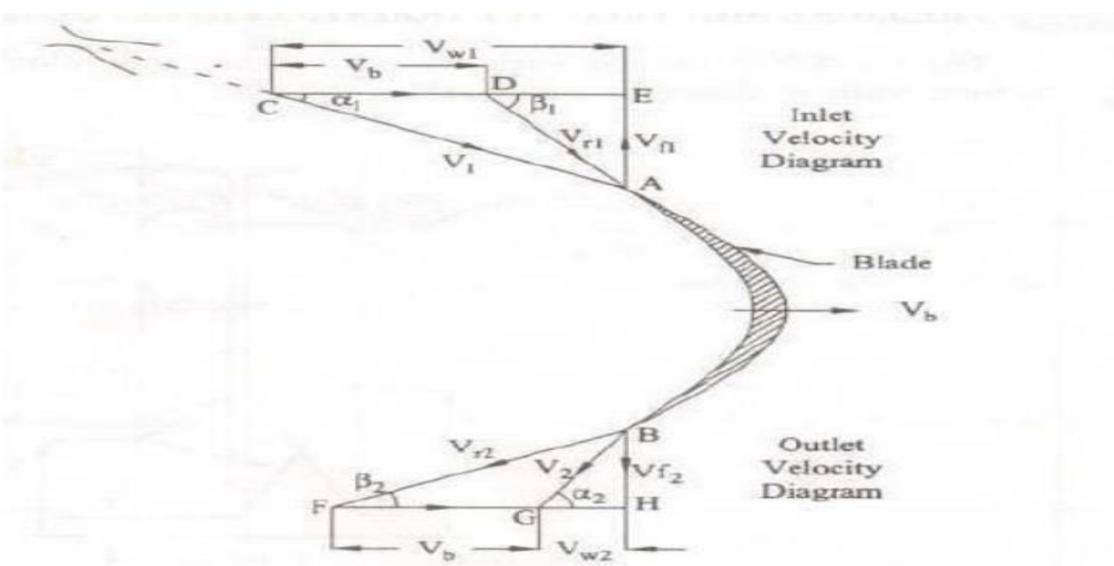


Pressure velocity compounding

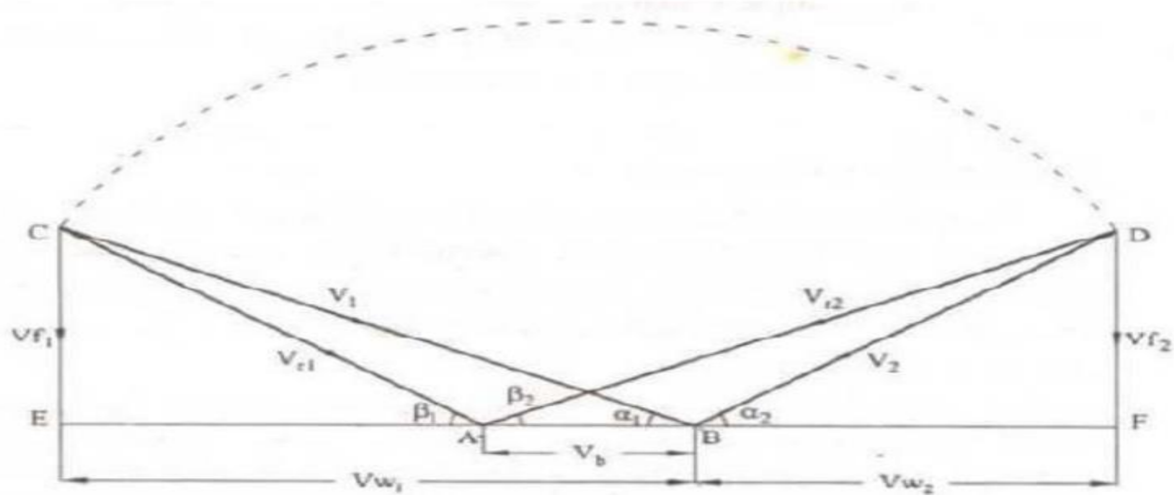
This method of compounding is the combination of two previously discussed methods. The total drop in steam pressure is divided into stages and the velocity obtained in each stage is also compounded. The rings of nozzles are fixed at the beginning of each stage and pressure remains constant during each stage as shown in figure. The turbine employing this method of compounding may be said to combine many of the advantages of both pressure and velocity staging By allowing a bigger pressure drop in each stage, less number stages are necessary and hence a shorter turbine will be obtained for a given pressure drop.

Velocity Diagram and Analysis of Impulse and Reaction Turbines

We should be able to calculate the propelling force applied to the turbine rotor. We can estimate work done and hence power. Since the force is due to change of momentum mainly caused by change in direction of flow of steam, it is essential to draw velocity diagram that shows how velocity of the steam varies during its passage through the blades. Velocity is vector quantity as it has magnitude and direction. So we can represent velocity by a straight line and its length indicates its magnitude and direction is indicated by direction of line with reference to some fixed direction



Velocity diagram for Impulse Turbine



2. Work done on blade = force ×distance

= tangential force × distance moved in unit time in the direction of force

$$= F_t \cdot V_b \; N-m/sec$$

$$= m \cdot (V_{\omega 1} \pm V_{\omega 2}) \cdot V_b \; N-m/sec$$

3. Power developed by the turbine = rate of doing work

$$= m \cdot (V_{\omega 1} \pm V_{\omega 2}) \cdot V_b \text{ watts.}$$

4. Axial thrust on the rotor = Fa= mass × axial acceleration

= mass × change in velocity of flow

$$= m \cdot (V_{f1} - V_{f2}) \text{ Newtons.}$$

Efficiencies:- Following efficiencies are common to both impulse and reaction turbines:-

1) Blading or diagram efficiency

2) Gross or stage efficiency

3) Nozzle efficiency

1. Diagram efficiency or blading efficiency

$$\eta_{bl} = \frac{\text{Work done on blade}}{\text{Energy supplied blade}}$$

$$= \frac{m \cdot (V_{\omega 1} \pm V_{\omega 2} \cdot V_b}{\frac{1}{2} m V_1{}^2}$$

$$= \frac{2 V_b \cdot (V_{\omega 1} \pm V_{\omega 2})}{V_1{}^2}$$

This is called diagram efficiency because the quantities involved in it are obtained from velocity diagram.

2. Gross or Stage Efficiency

$$\text{Stage efficiency} = \frac{\text{Work done on blade}/kg \text{ of steam}}{\text{Total energy supplied}/\text{stage}/kg \text{ of steam}}$$

$$\eta_{\text{stage}} = \frac{(V_{\omega 1} \pm V_{\omega 2} \cdot V_b}{h_1 - h_2}$$

3. Nozzle Efficiency

$$\text{Nozzle efficiency} = \frac{\text{Energy availbale at entrance}/kg}{\text{Enthalpy drop through a stage}/kg \text{ of steam}}$$

$$\eta_{\text{nozzle}} = \frac{\frac{1}{2} V_1{}^2}{(h_1 - h_2)}$$

$$= \frac{V_1{}^2}{2\,(h_1 - h_2)}$$

Forces on blade and WD by the blades

1. Force on rotor= mass × tangential acceleration

$$= m \times (V_{\omega 1} - V_{\omega 2})$$

Where m = mass flow rate of steam in kg/sec

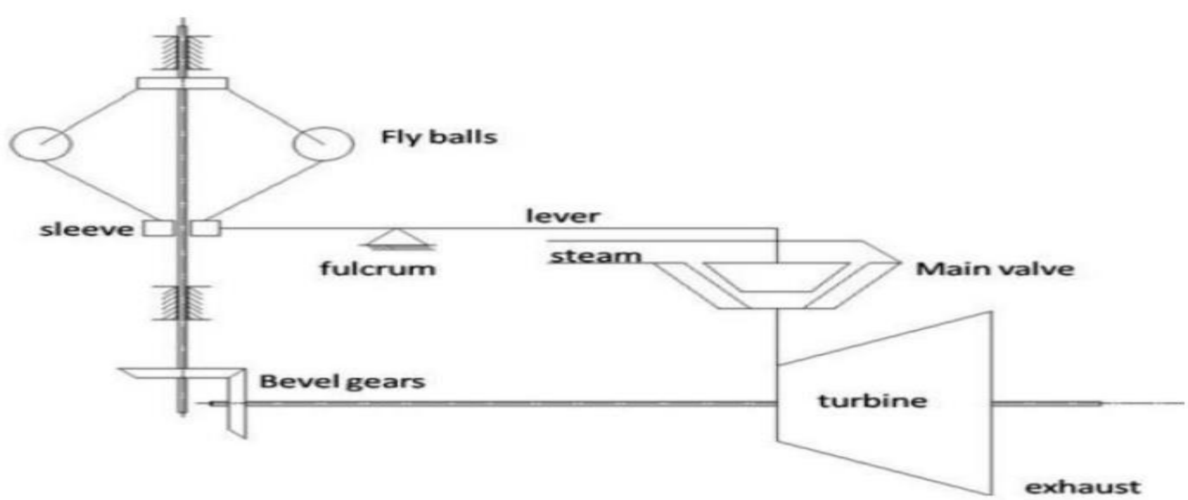
Actually Vw2 is negative as the steam is discharged in opposite direction to blade motion , so Vw1 and Vw2 are added together. Generally,

$$F_t = m\,(V_{\omega 1} \pm V_{\omega 2}) \text{ Newton.}$$

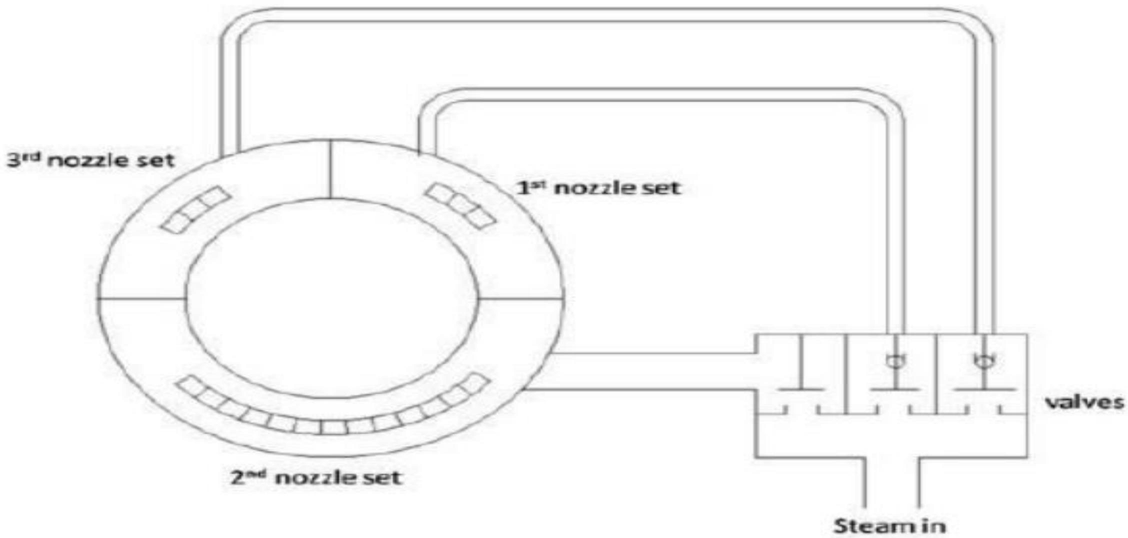
3. Governing of Steam Turbines

The main function of the governing is to maintain the speed constant irrespective of load on the turbine. The different methods which are commonly used for governing the steam turbines are listed below:- 1) Throttle governing 2) Nozzle control governing 3) By-pass governing

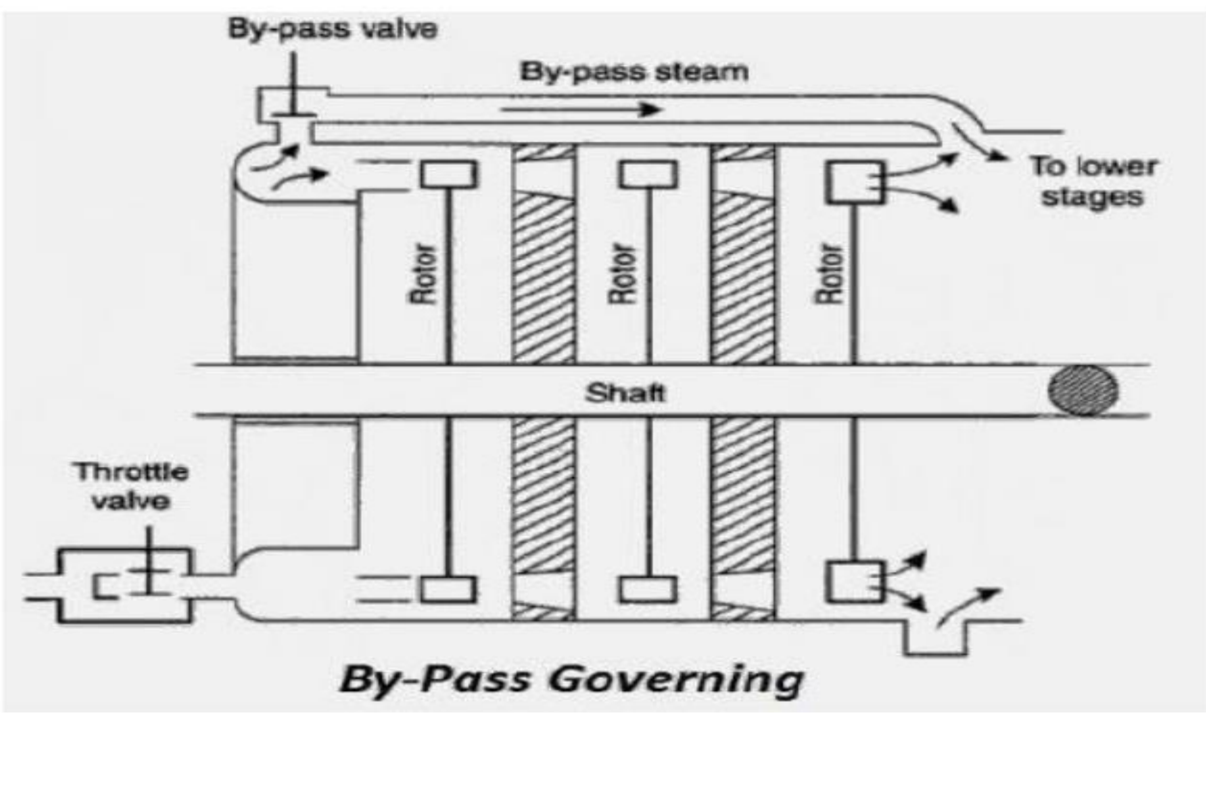
Throttle Governing



Nozzle Control Governing



Bypass Governing



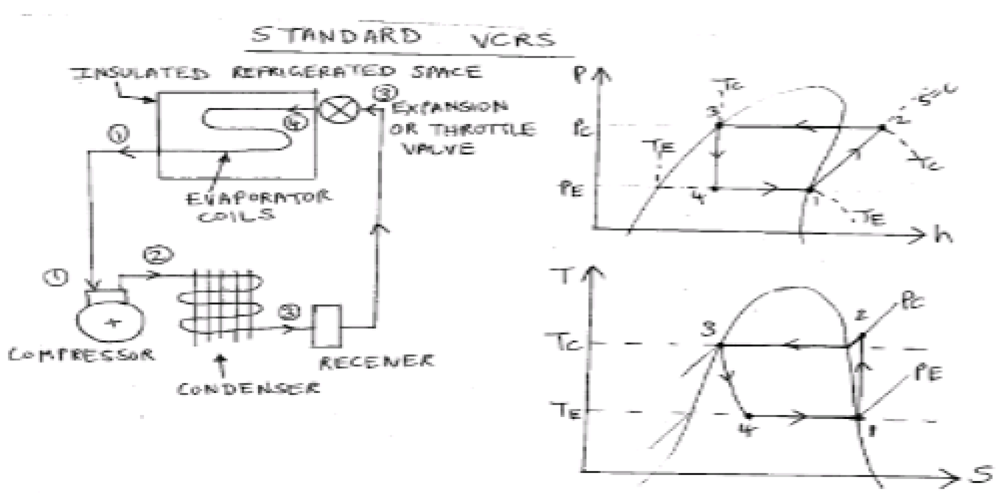
UNIT-V

Difference between Vapour Compression and Vapour Absorption:

Here are the 10 Points on differences between Vapour Compression and Vapour Absorption Refrigeration System:

Sl No	Vapour Compression	Vapour Absorption
1.	Vapor compression has high C.O.P (Coefficient of Performance).	It has low C.O.P (Coefficient of Performance).
2.	The charging of refrigerant is simple.	The charging of refrigerant is difficult.
3.	A possibility of leakage of refrigerant is more.	A possibility of leakage of refrigerant is less.
4.	Performance is adversely affected by part loads.	Reduced loads have no effect on its performance.
5.	It can not be located outside without shelter.	It can be located outside without shelter.
6.	It is less bulky.	It is bulky.

1.Vapour compression cycle(VCR)



a) Process 1-2: Isentropic compression in compressor

Vapour refrigerant is compressed to increase pressure from P1 to P2. This results in increase in temperature from t1 to t2.

P1=PEPE i.e.evaporator pressure
P2= PCPC i.e.condenser pressure
b) Process 2-3: Constant pressure heat rejection in condenser

Heat is rejected by superheated vapour refrigerant in condenser to the ambient air. This results in condensation of vapour into saturated liquid at pressure Pc.

c) Process 3-4: Throttling process in expansion valve

It is an isentropic process which results in pressure drop from Pc to P_E. This process involves increase in entropy which results in conversion of part of liquid refrigerant into vapour.

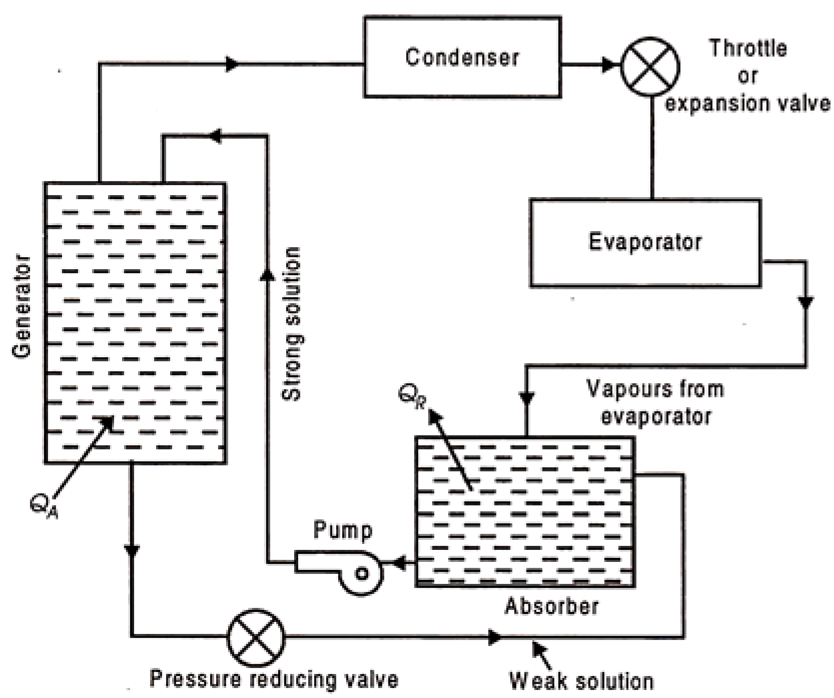
d) Process 4-1: Constant pressure heat addition in evaporator

Wet vapour refrigerant absorbs heat from air in refrigerating space. This converts wet vapour refrigerant into dry saturated vapour. This causes refrigeration.

2.Vapour Absorption Refrigeration System (with diagram) | Refrigeration

Vapour Absorption Refrigeration System (with diagram)!

Simple Vapour Absorption Cycle:



The most commonly used fluids in the absorption system are water as absorbent and ammonia as refrigerant. The vapour from the evaporator is allowed to be mixed and absorbed in the absorber. The heat of absorption generated in the process is rejected from the absorber to the circulating cold water in a heat exchanger dipped in the solution contained in the absorber.

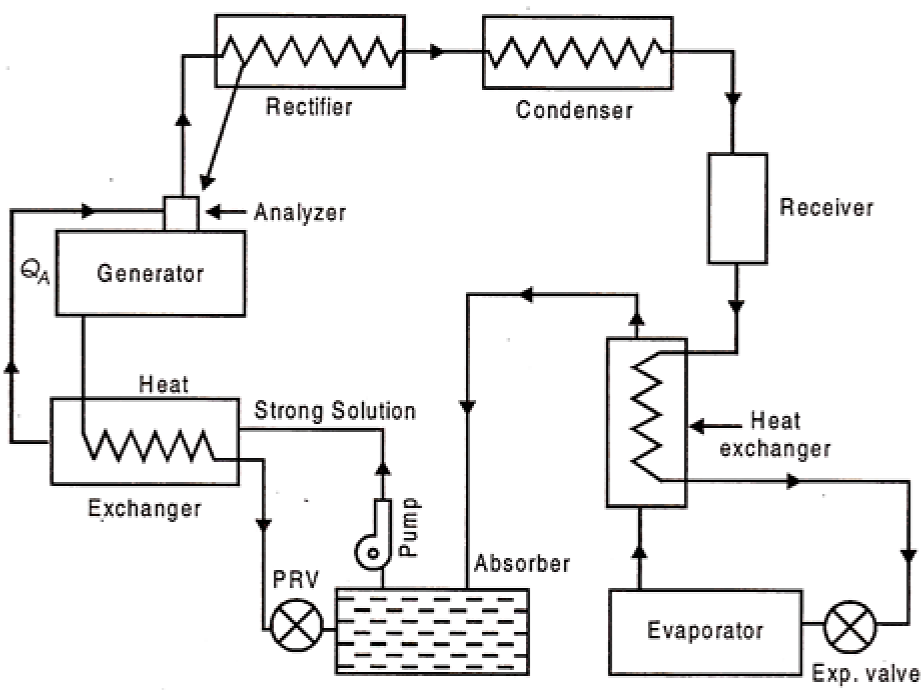
The strong aqua-ammonia solution from the absorber is pumped upto the condenser pressure and fed to the generator which is the main energy consuming element of the system. Heat is supplied to the generator. The boiling point of refrigerant NH_3, is lower than that of the absorbing liquid H_2O, hence the vapours leaving the generator are predominantly those of refrigerant.
These vapours then pass on to the condenser. The liquid refrigerant from the condenser, then, passes through an expansion valve or throttle valve to the evaporator where it absorbs heat from the substances or bodies to be refrigerated. Liquid refrigerant is then evaporated and the vapours enter the absorber completing the cycle.

The weak aqua-ammonia solution in the generator left due to separation of refrigerant vapour is drained back to the absorber for repeating the cycle.

The weak aqua-ammonia solution leaving the generator is at high pressure and the pressure in the absorber is the evaporator pressure which is less than the generator or condenser pressure, and hence a pressure reducing valve is provided in the weak solution line to the absorber.

The energy requirements of the system are at the generator and at the pump as compared to those at compressor in the vapour compression system. Since the volume of liquid handled by the pump is too small, the power required here is almost negligible as compared to that by the generator.

Practical Absorption Refrigeration Cycle:
The replacement of the compressor by the simple arrangement of Fig. 36.33 is not very economical in practice. In order to make improvements certain additional auxiliary items are provided in the system. They include analyzer, a rectifier, and two heat exchangers. The practical absorption cycles as developed after incorporating these auxiliaries



a) Analyzer:

The ammonia vapours leaving the generator may contain certain moisture, and therefore it should be freed from any trace of water vapour before passing on to the condenser and then to the expansion valve, otherwise the water vapour is likely to freeze in the small valve passage and choke the flow.

The function of the analyzer is to remove the moisture as far as possible. It is an open types of cooler and forms an integral part of the generator, mounted on its top. Both the strong aqua-ammonia solution from the absorber and the condensate removed in rectifier are introduced from the top and flow downwards.

The hot rising vapour of ammonia therefore comes in contact with the same and gets cooled. Thus most of the water vapour is condensed and drips back into the generator. This helps in salvaging a certain portion of heat in outgoing vapour which would otherwise have been rejected out through the condenser.

3.Properties of Refrigerants:

Physical Properties of Refrigerants

- Low Freezing Point. Refrigerants should have low freezing point than the normal operating conditions. ...
- Low Condensing Pressure. ...
- High Evaporator Pressure. ...

- High Critical Pressure. ...
- High Vapor Density. ...
- High Dielectric strength. ...
- High Latent Heat of Vaporization. ...
- High Heat Transfer Coefficient.

4.PSYCHROMETRY TERMS

1. Dry air. The pure dry air is a mixture of a number of gases such as nitrogen, oxygen, carbon dioxide, hydrogen, argon, neon, helium etc. But the nitrogen and oxygen have the major portion of the combination

2. Moist air. It is a mixture of dry air and water vapour. The amount of water vapour present. in the air depends upon the absolute pressure and temperature of the mixture.

3. Saturated air. It is mixture of dry air and water vapour, when the air has diffused the maximum amount of water vapour into it. The water vapours, usually, occur in the form of superheated steam as an invisible gas. However, when the saturated air is cooled, the water vapour in the air starts condensing, and the same may be visible in the form of moist, fog or condensation on cold surfaces.

4. Degree of saturation. It is the ratio of actual mass of water vapour in a unit mass of dry air to the mass of water vapour in the same mass of dry air when it is saturated at the same temperature.

5. Humidity. It is the mass of water vapour present in 1 kg of dry air, and is generally expressed in terms of gram per kg of dry air (g / kg of dry air). It is also called specific humidity or humidity ratio.

6. Absolute humidity. It is the mass of water vapour present in 1 m3 of dry air, and is generally expressed in terms of gram per cubic metre of dry air (g /m3 of dry air). It is also expressed in terms of grains per cubic metre of dry air. Mathematically, one kg of water vapour is equal to 15 430 grains.

7. Relative humidity. It is the ratio of actual mass of water vapour in a given_volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure. It is briefly written as RH.

8. Dry bulb temperature. It is the temperature of air recorded by a thermometer, when it is not affected by the moisture present in the air. The dry bulb temperature (briefly written as DBT) is generally denoted by td or tdb.

9. Wet bulb temperature. It is the temperature of air recorded by a thermometer, when its bulb is surrounded by a wet cloth exposed to the air. Such a thermometer is called *wet bulb thermometer. The wet bulb temperature (briefly written as WBT) is generally denoted by tw or twb.

10. Wet bulb depression. It is the difference between dry bulb temperature and wet bulb temperature at any point. The wet bulb depression indicates relative humidity of the air.

11.Dew point temperature. It is the temperature of air recorded by a thermometer, when the moisture (water vapour) present in it begins to condense. In other words, the dew point temperature is the saturation temperature (tsat). C

5.DALTON'S LAW OF PARTIAL PRESSURES It states, The total pressure exerted by the mixture of air and water vapour is equal to the sum of the pressures, which each constituent Fould exert, if it occupied the same space by itself. In other words, the total pressure exerted by air and water vapour mixture is equal to the barometric pressure. Mathematically, barometric pressure of the mixture.

6.PSYCHROMETRIC PROCESSES The various psychrometric processes involved in air conditioning to vary the psychrometric properties of air according to the requirement are as follows:

1. Sensible heating,

2. Sensible cooling,

3. Humidification and dehumidification,

4. Cooling and adiabatic humidification,

5. Cooling and humidification by water injection,

6. Heating and humidification,

7. Humidification by steam injection,

8. Adiabatic chemical dehumidification,

9. Adiabatic mixing of air streams.

7.Classification of Air Conditioning Systems

The air conditioning systems may be broadly classified as follows:

1. According to the purpose (a) Comfort air conditioning system, and (b) Industrial air conditioning system.

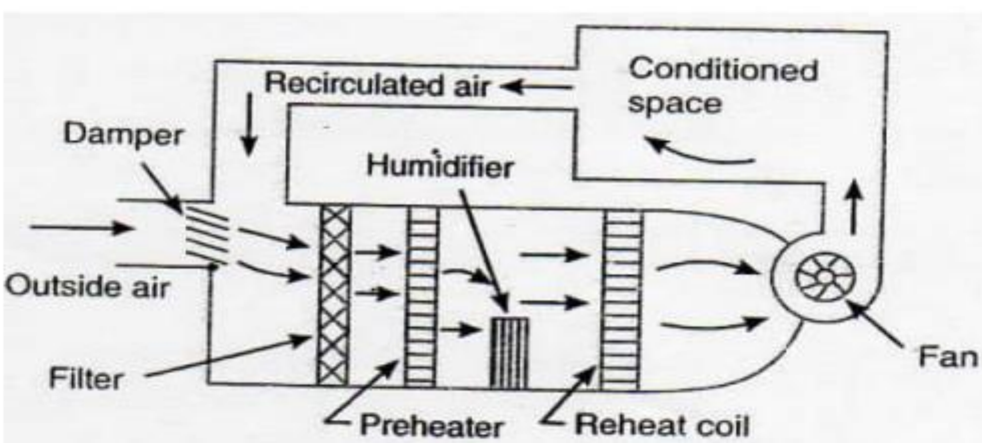
2. According to season of the year (a) Winter air conditioning system, (b) Summer air conditioning system, and (c) Year-round air conditioning system.

3. According to the arrangement of equipment (a) Unitary air conditioning system, and (b) Central air conditioning system.

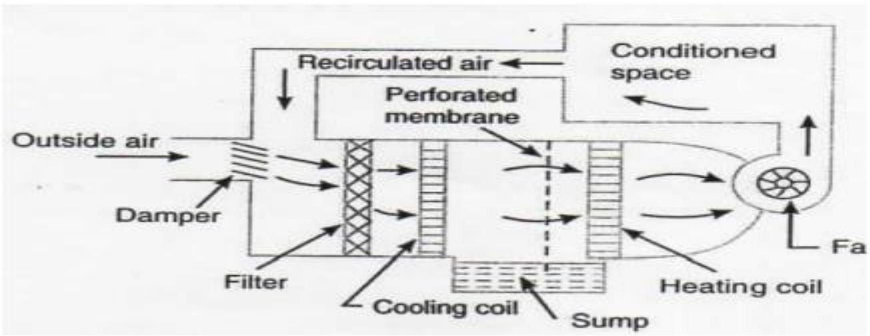
Winter Air Conditioning System

In winter air conditioning, the air is heated, which is generally -accompanied by humidification. The schematic arrangement of the system is Damper

The outside air flows through a damper and mixes up with the Outside air recirculated air (which is obtained Fan from the conditioned space). The Filter mixed air passes through a filter to remove dirt, dust and other impurities. The air now passes through a preheat coil in order to prevent the possible freezing of water and to control the evaporation of water in the humidifier. 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 used air is exhausted to the atmosphere by the exhaust fans or ventilators. The remaining part of the used air (known as re-circulated air) is again conditioned.



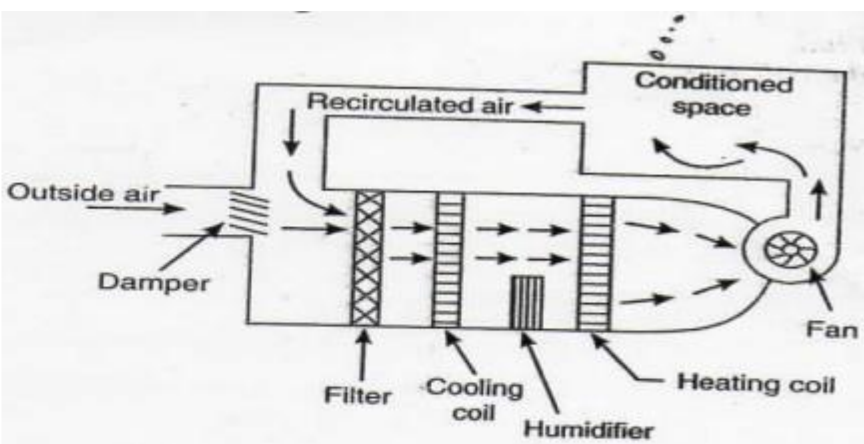
Summer Air Conditioning System



Now the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators. The remaining part of the used air (known as re-circulated air) is again conditioned -as shown in Fig. 4: The outside air is sucked and made-I6 mix with the recirculated air in order to make up for the loss of conditioned (or used) air through exhaust fans or ventilation from the conditioned space.

Year-Round Air Conditioning System

The year-round air conditioning system should have equipment for both the summer and winter air conditioning. The schematic arrangement of a modern summer year-round air conditioning system.



The outside air flows through the damper and mixes up with the Damper re-circulated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove dirt, dust and other impurities. In summer air conditioning, the cooling coil operates to cool the air to the desired value. The dehumidification is obtained by operating the cooling coil at a temperature lower than the dew point temperature (apparatus dew point). In winter, the cooling coil is made inoperative and the heating coil operates to heat the air. The spray type humidifier is also made use of in the dry season to humidify the air.