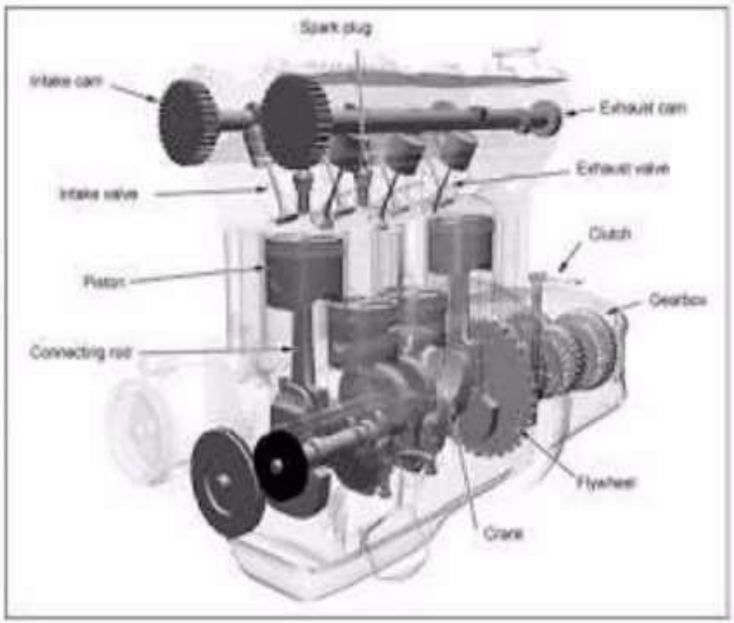
Unit - I

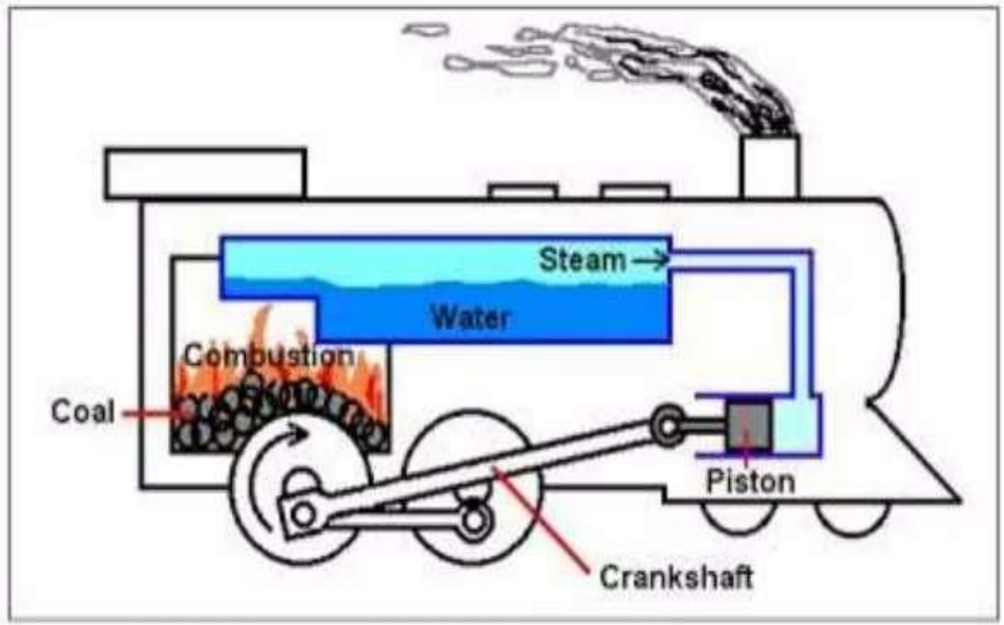
IC engines And Stages of Combustion in IC engines

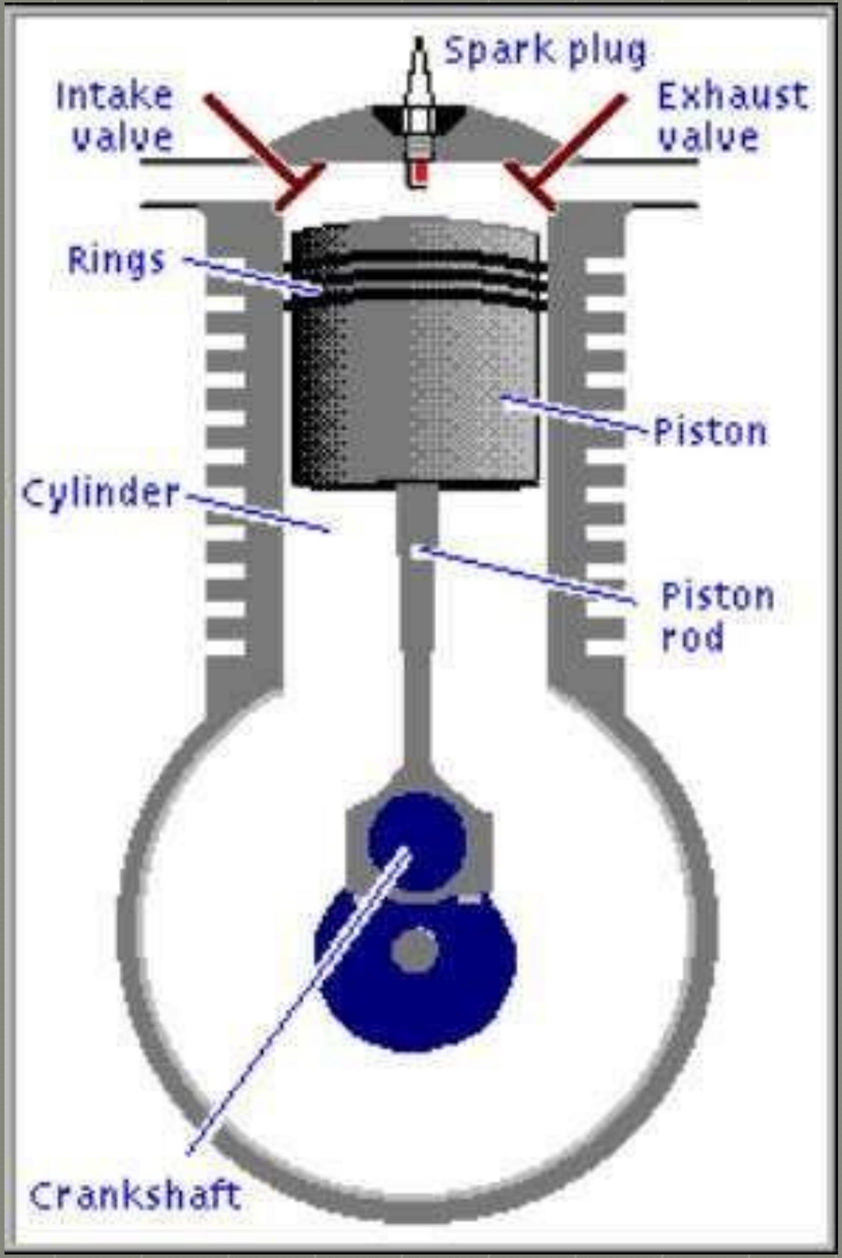
Heat Engine

Internal Combustion Engine (IC Engine)

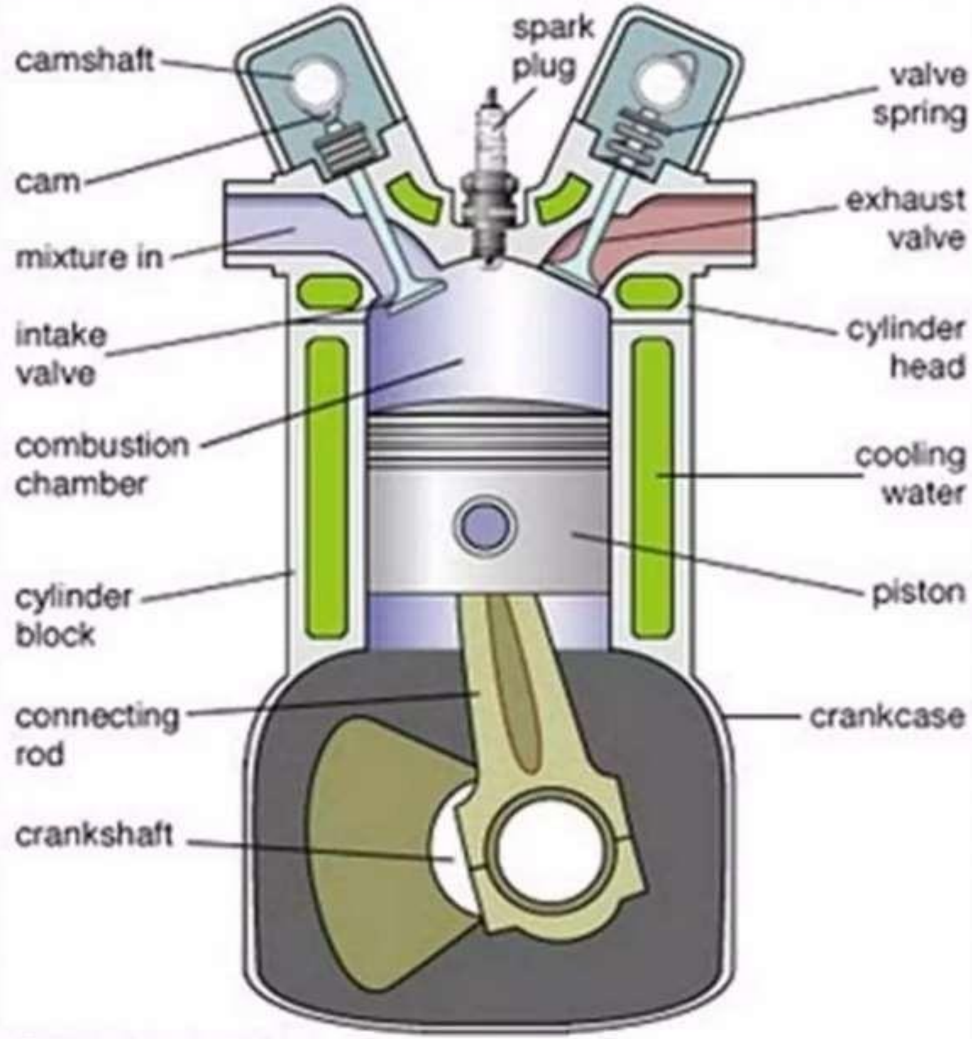
External Combustion Engine (EC Engine)





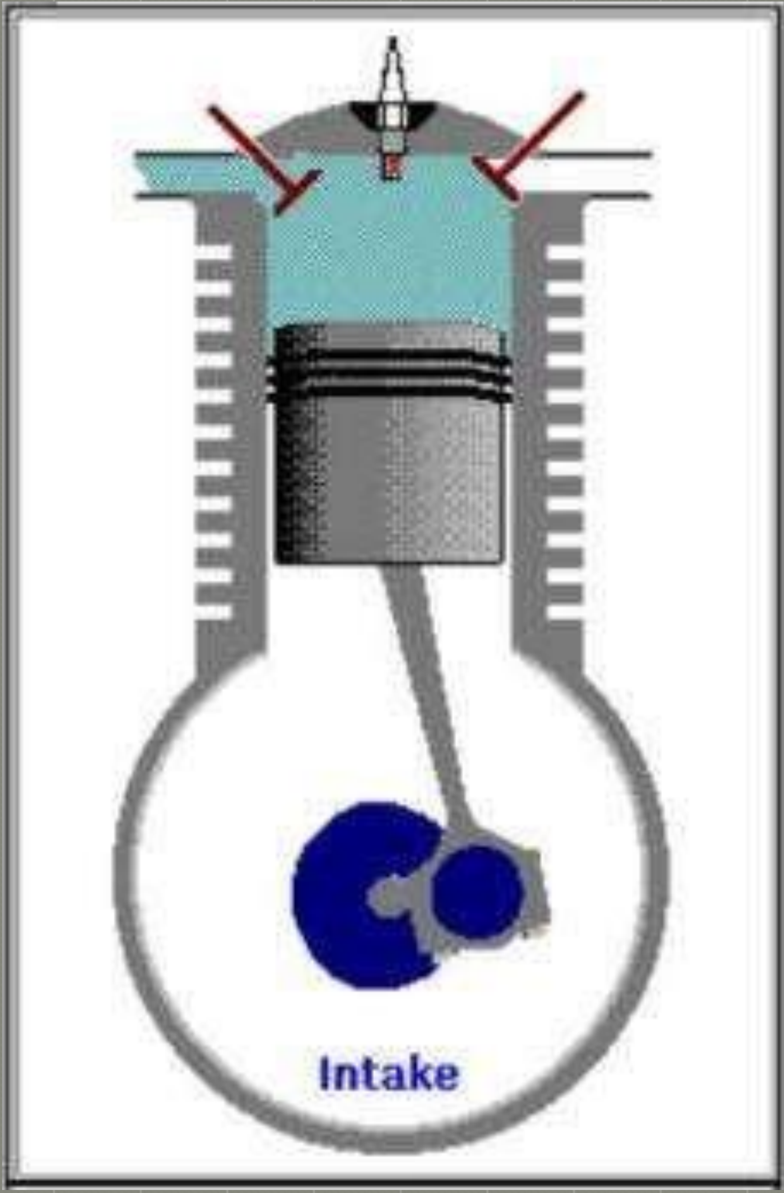

Spark plug
Intake valve
Exhaust valve
Rings
Piston
Cylinder
Piston rod
Crankshaft

Components of an IC Engine

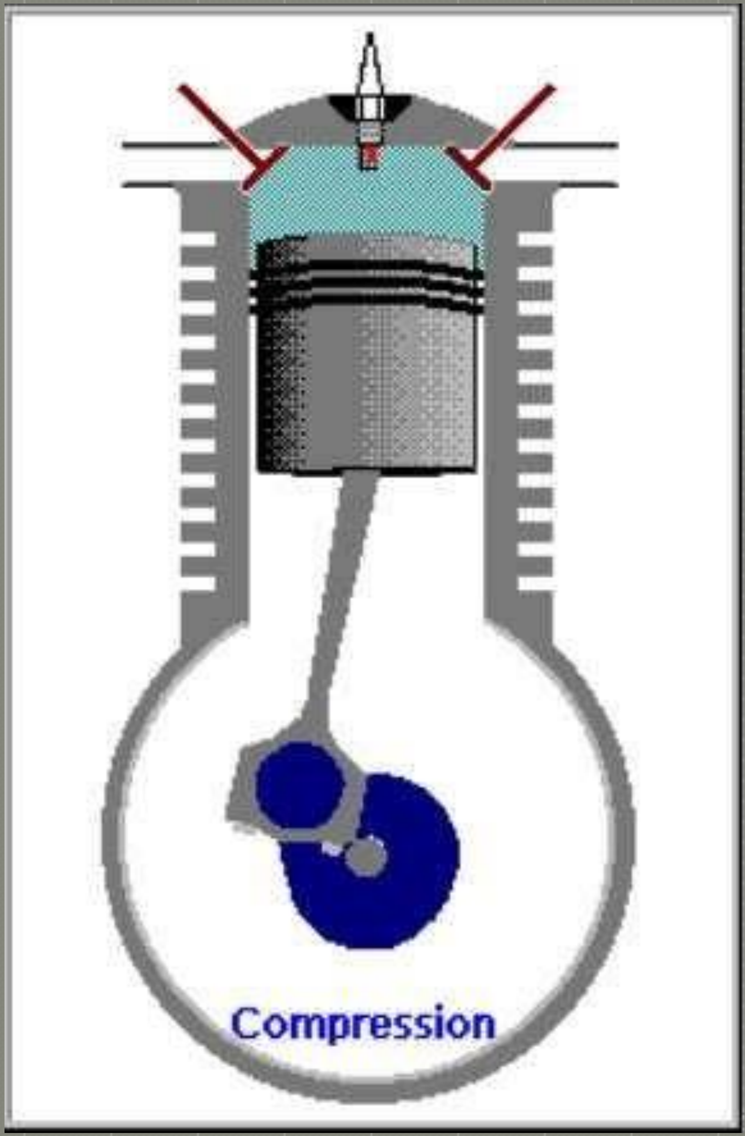


- The internal combustion of an engine is considered to be the heart of the automobile.
- They are defined as any engine that uses an explosive combustion of fuel and air to push a piston within a cylinder. Forming the repeating cycle known as the strokes.
- Intake, Compression, Power Stroke, and Exhaust are the four actions of one stroke.
- The difference between the two cycle and four cycle engine is the number of strokes it uses to start the fuel reaction of internal combustion.
- Diesel engines unlike gasoline do not need spark plugs to ignite the fuel. Instead it uses compression but undergoes the same principle of a stroke.

- This starts at the highest point known as top dead center and ends at bottom dead center
- The intake stroke allows the piston to suck fuel and air into the combustion chamber through the intake valve port.

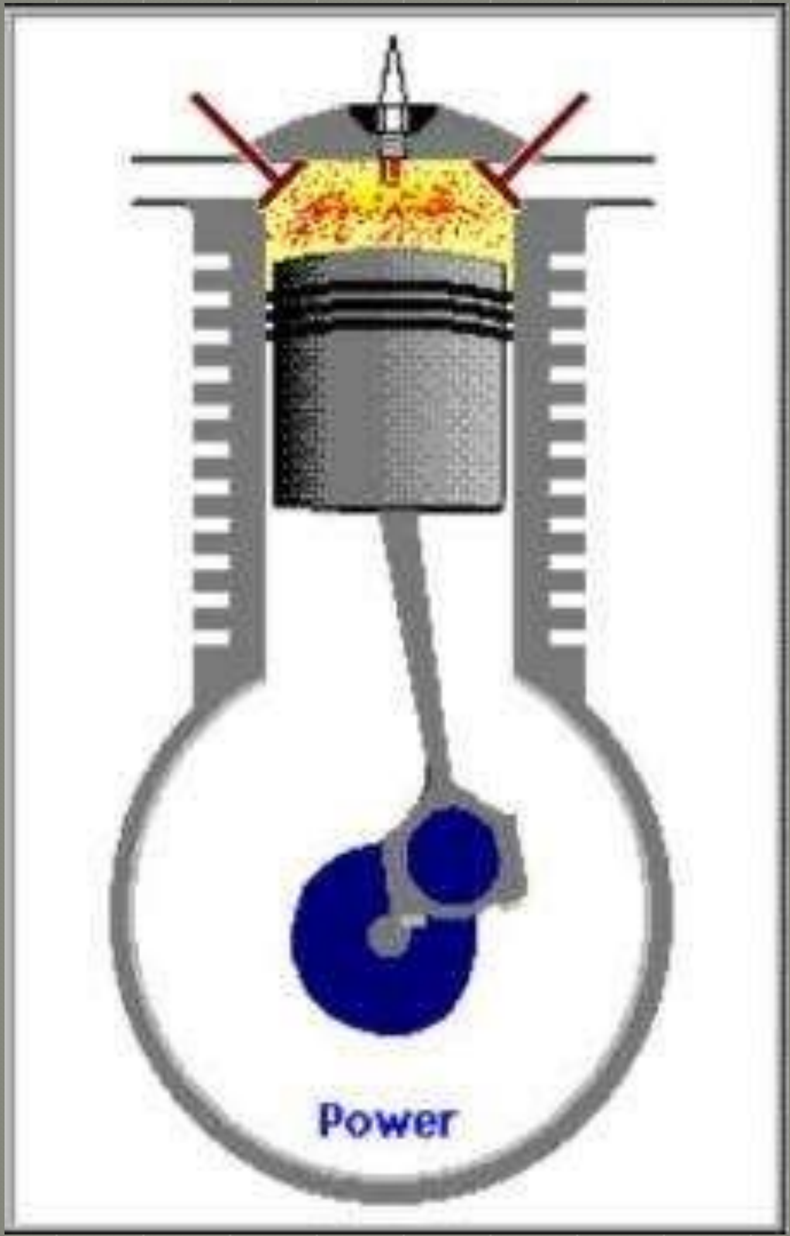


- Compression starts at bottom dead center and ends at top dead center.
- The second motion of the stroke takes all the fuel and air that was stored and compresses it into one tenth its original sizes. Making the air/fuel mixture increase in temperature preparing it for the next stage in its combustion cycle.



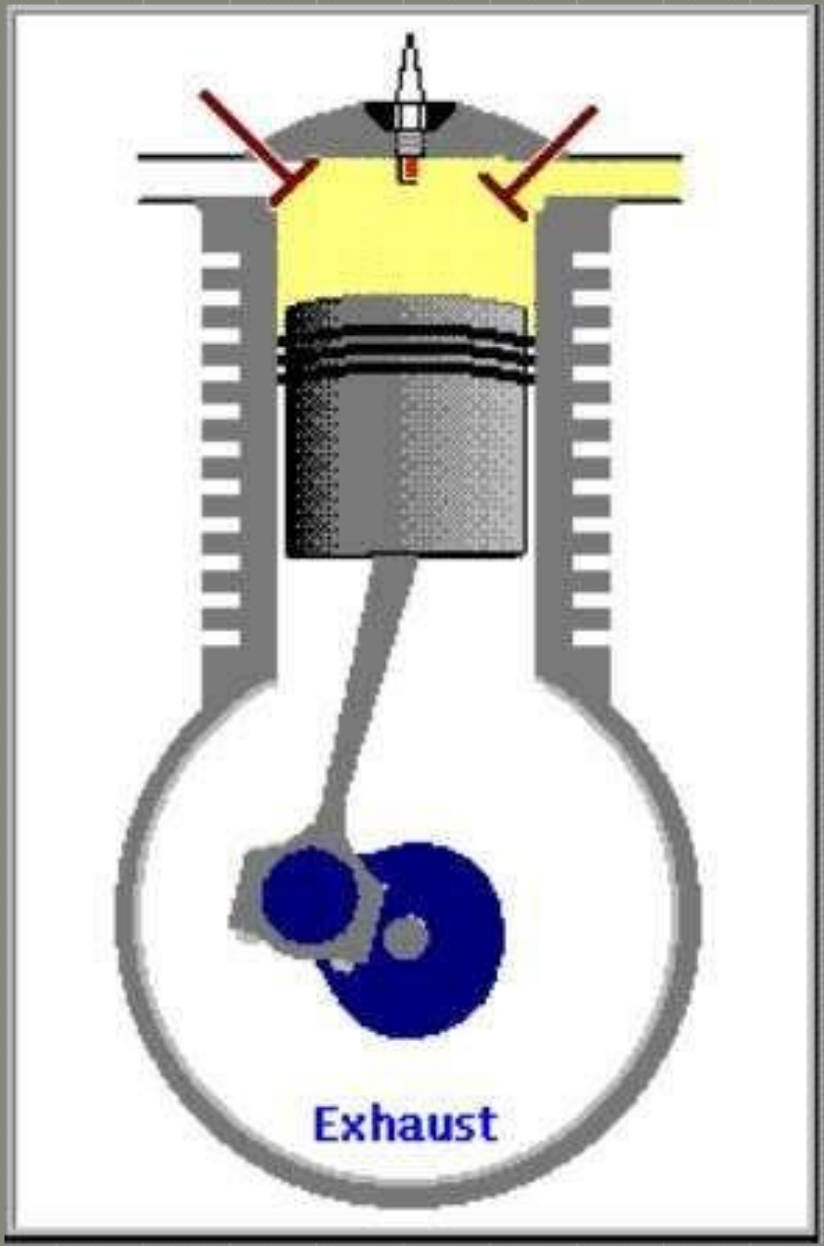
- The power stroke starts as soon as the piston reaches top dead center allowing the spark plug to ignite.

- This electric current created by the spark plug ignites the fuel and air mixture sending the piston back down the cylinder with a pressure reaching high as 600 PSI.

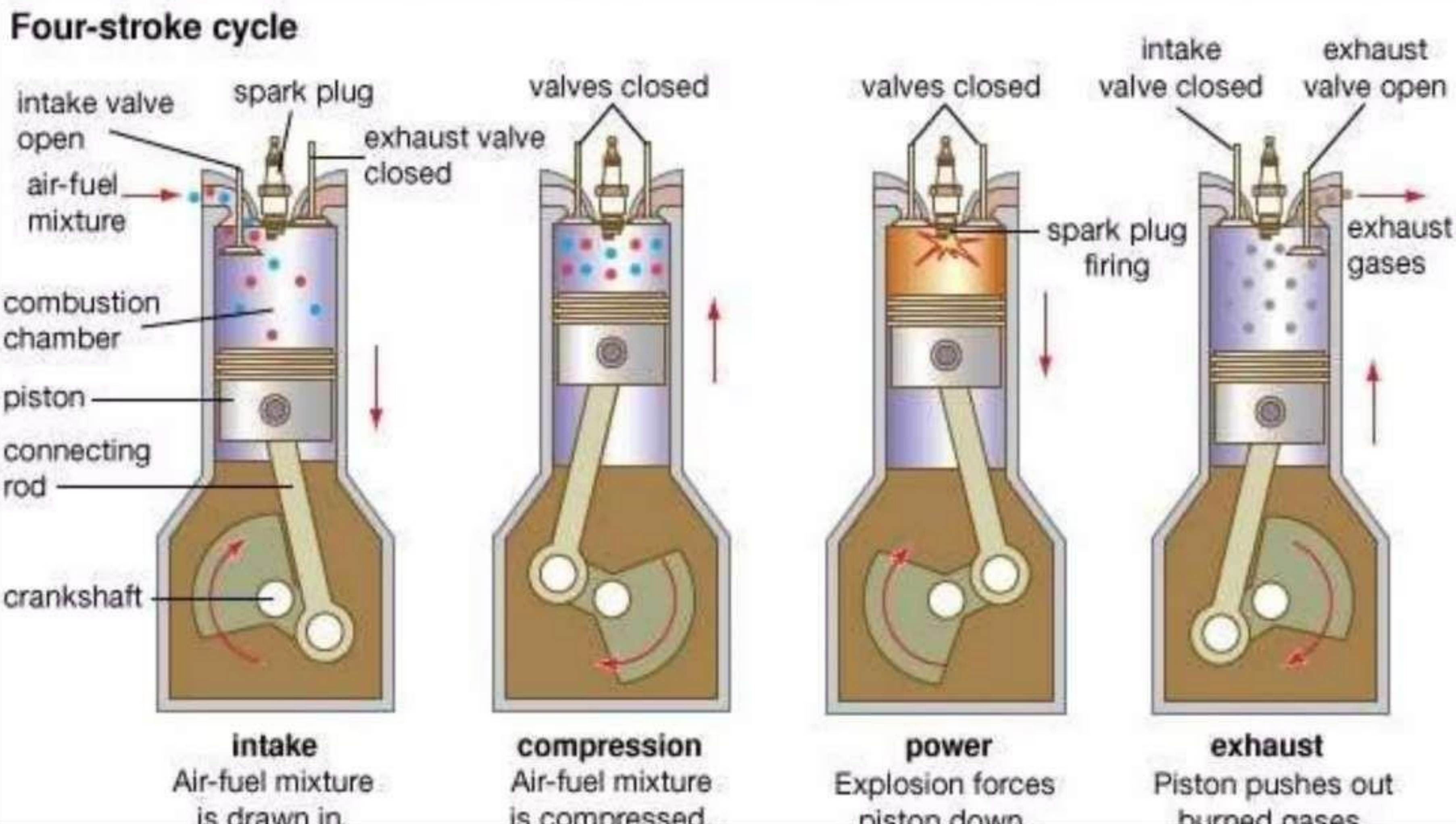


- The final stage of the stroke releases all the burned fuel through the exhaust valve.

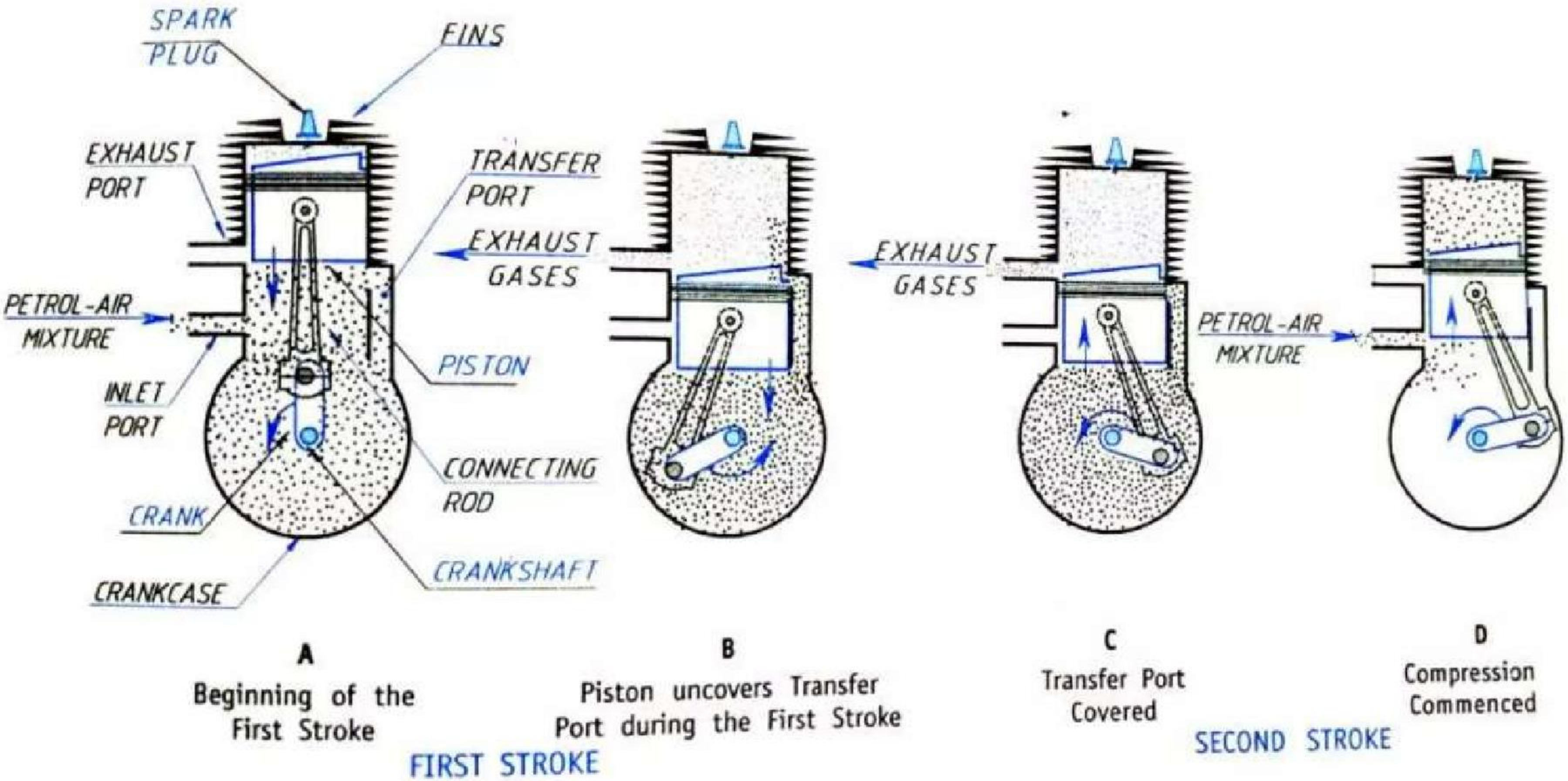
- As the piston moves from bottom dead center to top dead center it takes all the burned fuel and pushes it out of the cylinder, preparing it for the next cycle of strokes.



4 – Stroke Petrol Engine Working Principle

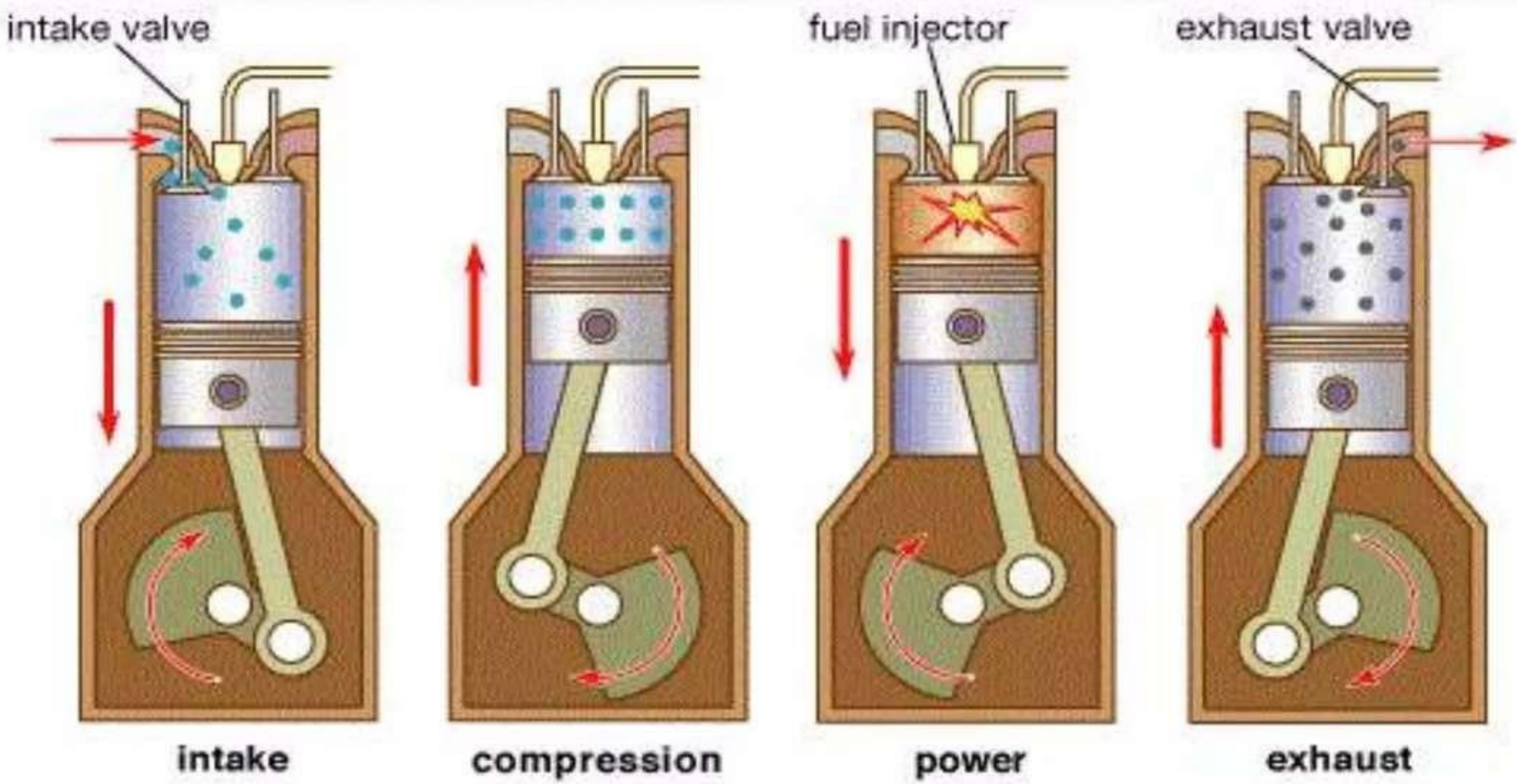


2 – Stroke Petrol Engine Working Principle

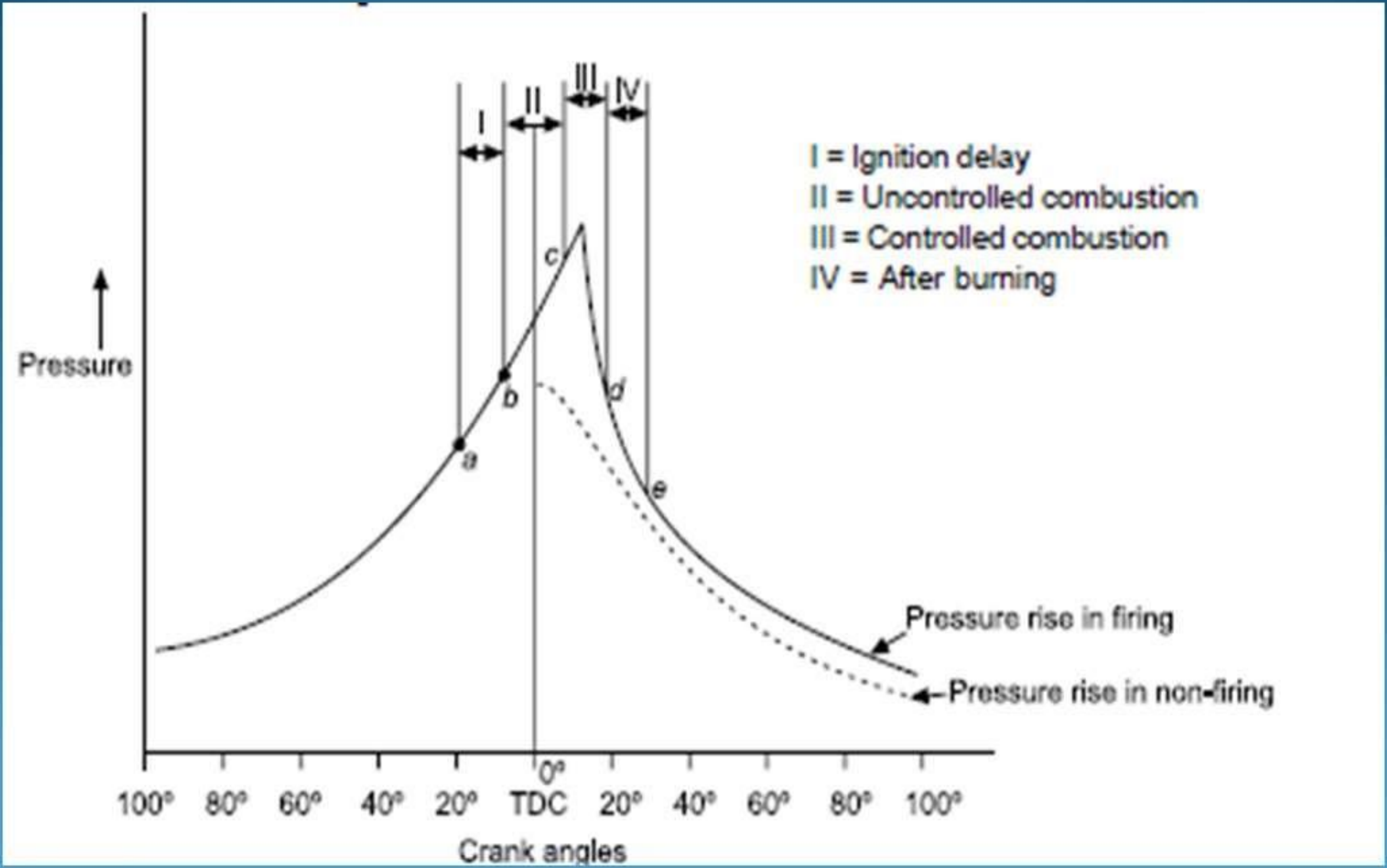


Diesel engines work on the same principle as the two and four stroke engines. They do not need a spark plug to ignite the fuel. During the intake stroke, air does not mixed with the fuel in the cylinder. Instead as the air reaches high enough compression Fuel is then sprayed into the cylinder creating ignition. This pushes the piston down the cylinder at a pressure of 500 PSI, starting the stroke all over again.

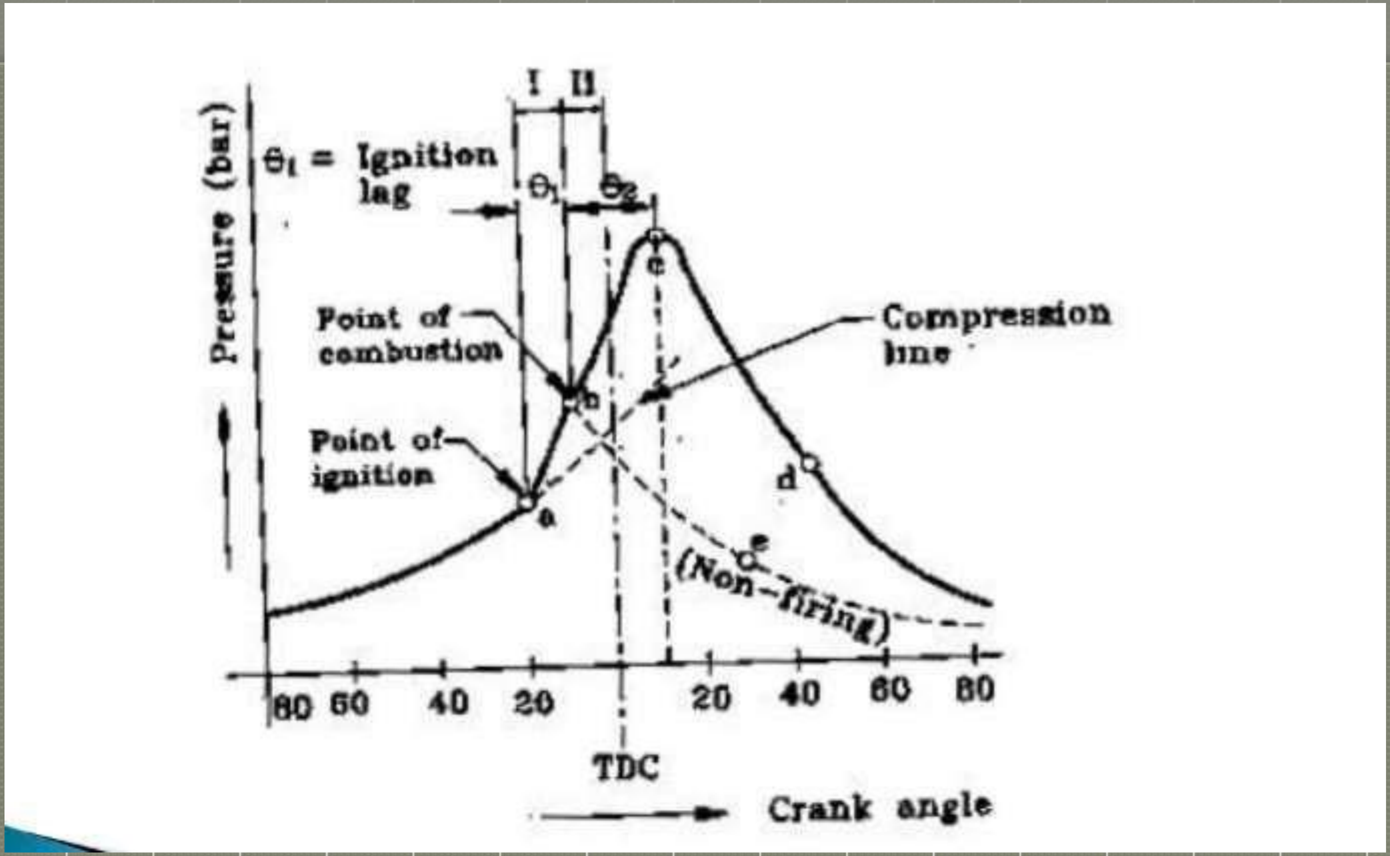
4 – Stroke Diesel Engine Working Principle



STAGES OF COMBUSTION IN CI ENGINES



Stages of Combustion in SI engine



- Unit-II

Air Compressors

Air compressor

- Pneumatics: A system which uses compressed air is called pneumatics.
- It deals with the study of behaviour & application of compressed air
- A basic pneumatic system consist of a source of compressed air, control valves, pipelines & pipe fittings and pneumatic accessories like filter, regulator and lubricator

Application of compressed air

- For operating pneumatic tools such as drills, screw drivers, hammers, chiessels
- For pneumatic cranes
- For pneumatic brakes of automobiles, railways and presses
- For agricultural accessories such as dusters and sprayers
- For drive of CNC machine tools
- For pneumatic conveying of materials
- For pneumatic gauging, inspection and low cost automation systems

Introduction to compressors

- An air compressor is a mechanical device that increases the pressure of air by reducing volume.
- Air is compressible, the compressor reduces the volume of air and induces pressure in the air
- An air compressor converts electrical energy into kinetic energy in the form of the air

Classification of air compressor

- Air compressors are classified according to method of energy transfer and pressure generation i.e. positive displacement and dynamic compressors
- Positive displacement compressors work on the principle of increasing the pressure of air by reducing the volume of air in an enclosed chamber

Classification of air compressor

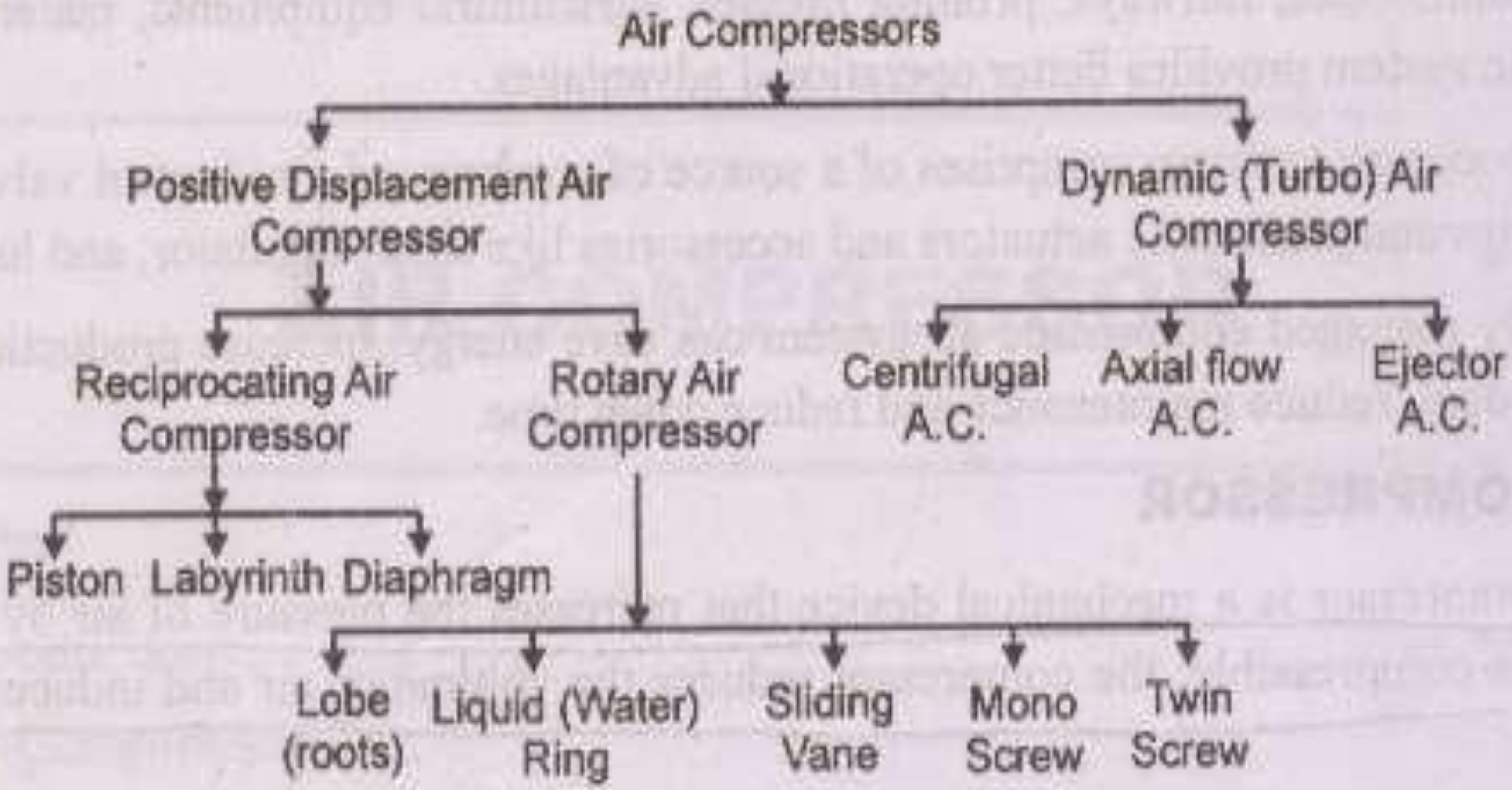


Fig. 9.1 : Classification of air compressor

Reciprocating Air compressors

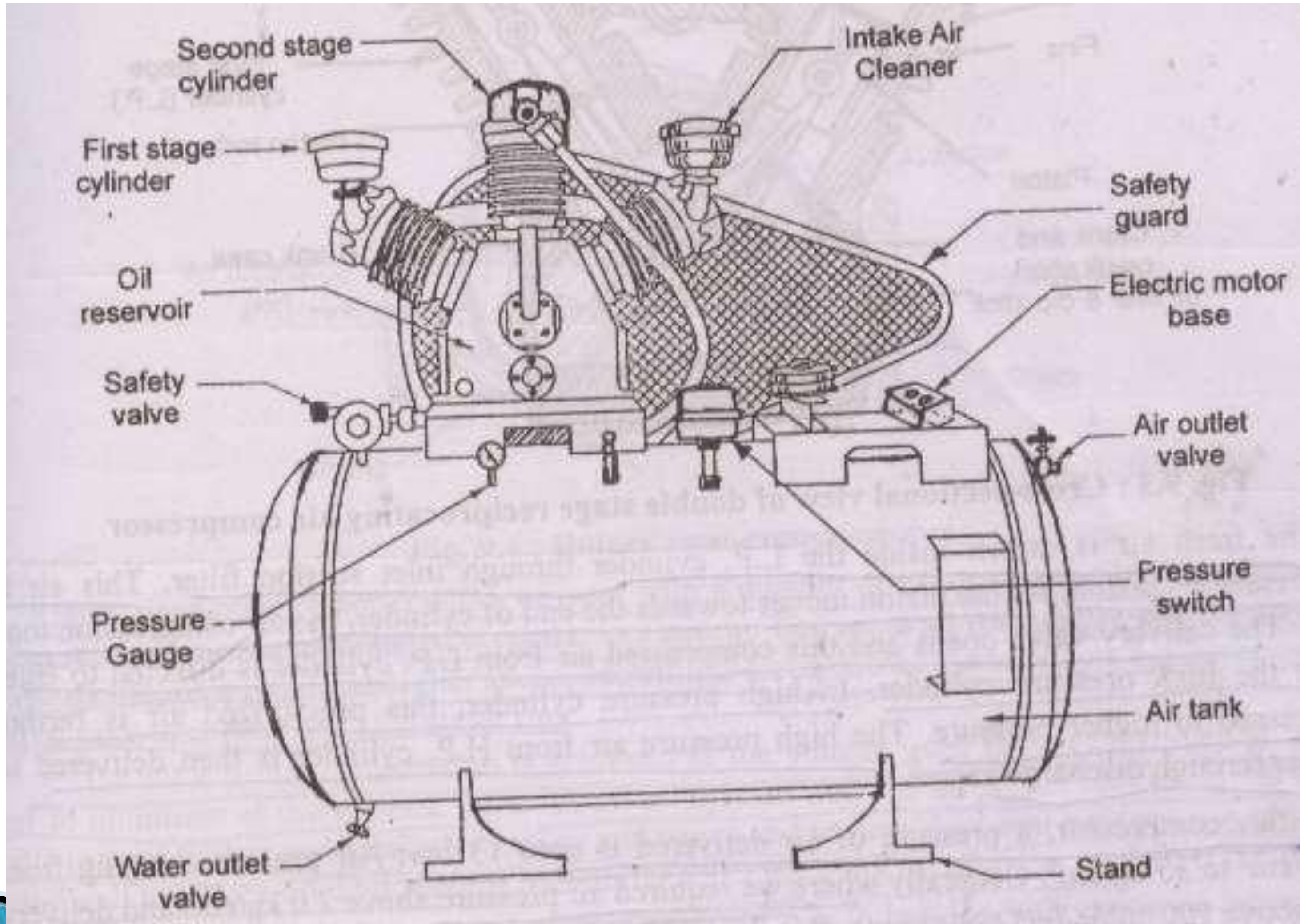


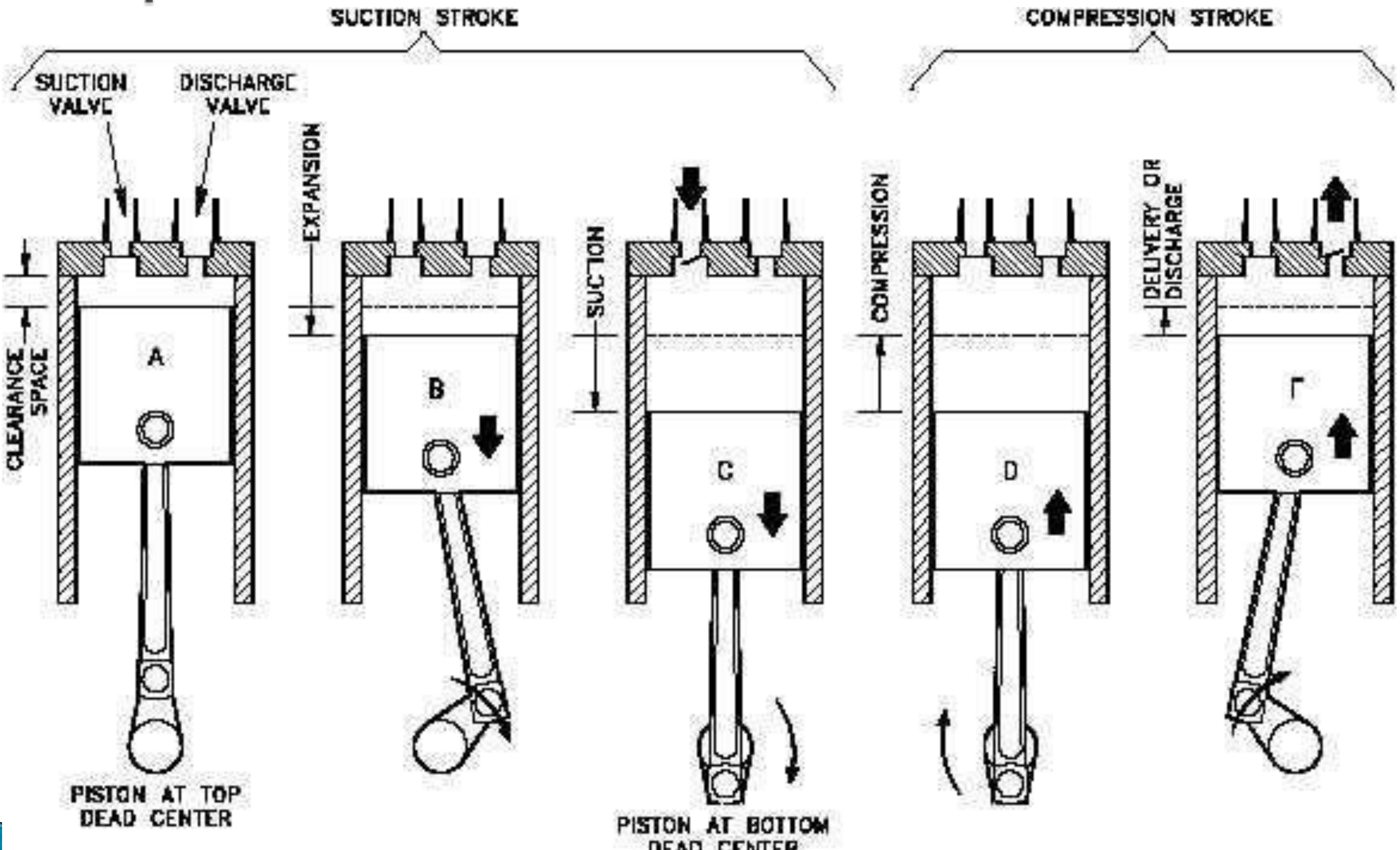
Fig. 9.2 : Double stage reciprocating air compressor

Reciprocating Air compressors

- A reciprocating air compressor consist of a piston which is enclosed within a cylinder and equipped with suction and discharge valve
- The piston receives power from electric motor or IC engine.

  - Reciprocating air compressors are positive displacement type of air compressors.
  - These are piston & diaphragm type, vane type, gear type, screw type compressors.

Single stage reciprocating air compressor



Double stage reciprocating air compressor

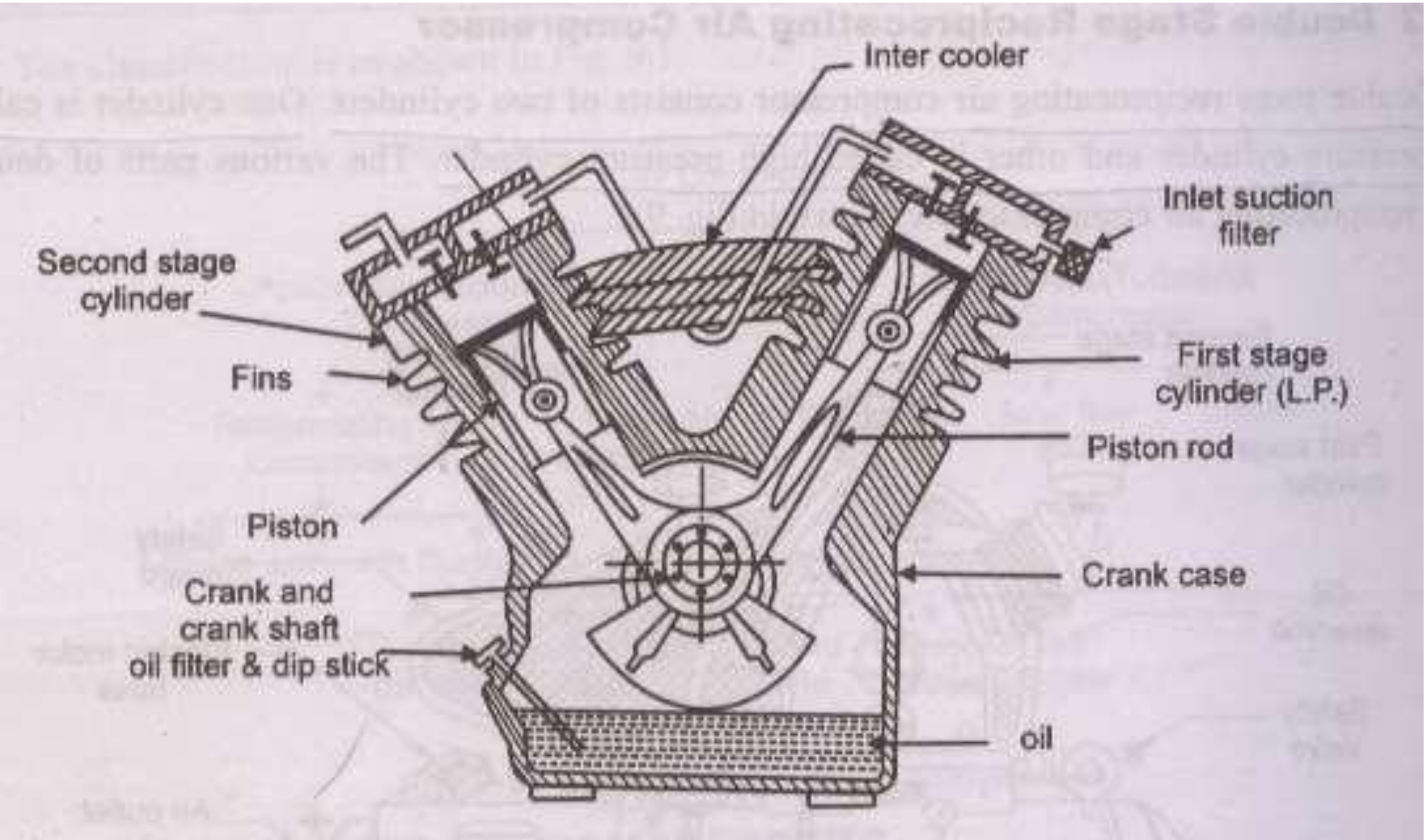


Fig. 9.3 : Cross-sectional view of double stage reciprocating air compressor

Advantages

- Simple in design
- Lower initial cost
- Easy to install
- Higher effeiciency

Disadvantages

- Number of moving parts are more
- Higher maintenance cost
- Heavy foundation is required as it has vibration problem
- Cannot run at full capacity

Rotary vane compressor

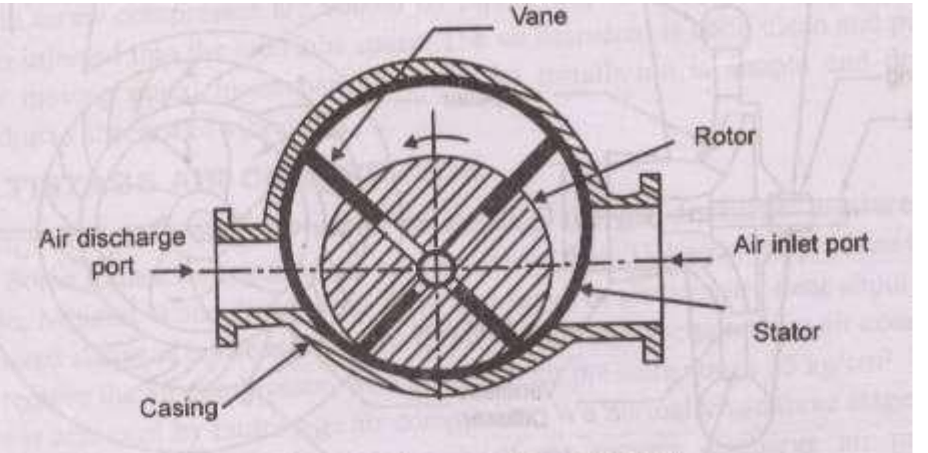


Fig. 9.4 : Rotary vane compressor

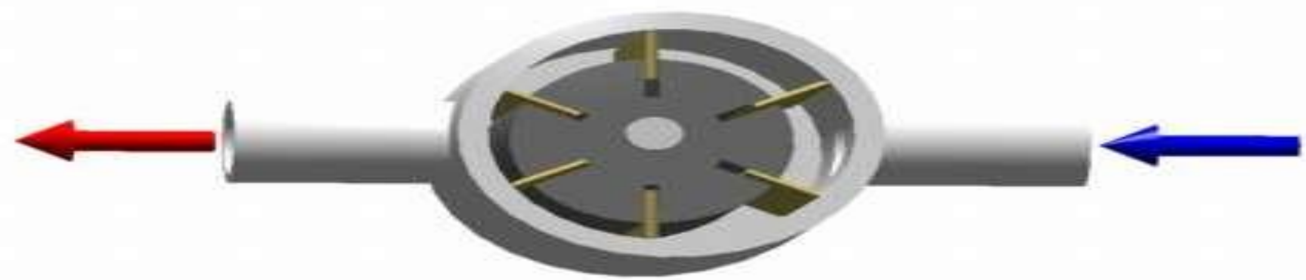
Rotary vane compressor

- The rotor is mounted eccentric in a casing.
- The vanes slides radially in and out of the rotor.
- As the rotor rotates at higher speed, centrifugal force throws the vanes outward keeping the end of vane in contact with the stator ring.
  - As the rotor turns, compression is achieved as the volume goes from a maximum at intake port to minimum at the exhaust port.
  - An oil is injected into the air intake and along the stator walls to cool the air and lubricate bearing and vanes and to provide a seal between the vane and stator wall to reduce internal leakage.

Rotary vane compressor

- As the rotor turns, compression is achieved as the volume goes from a maximum at intake port to minimum at the exhaust port.
- An oil is injected into the air intake and along the stator walls to cool the air and lubricate bearing and vanes and to provide a seal between the vane and stator wall to reduce internal leakage.

Vane type rotary compressor



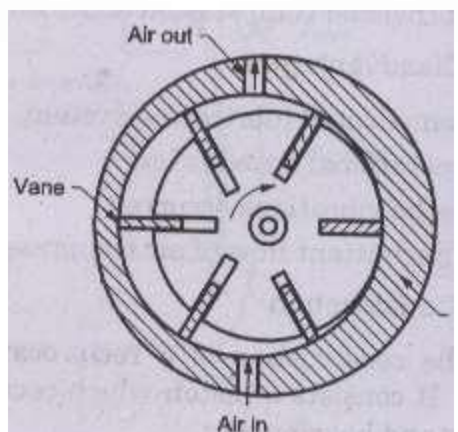
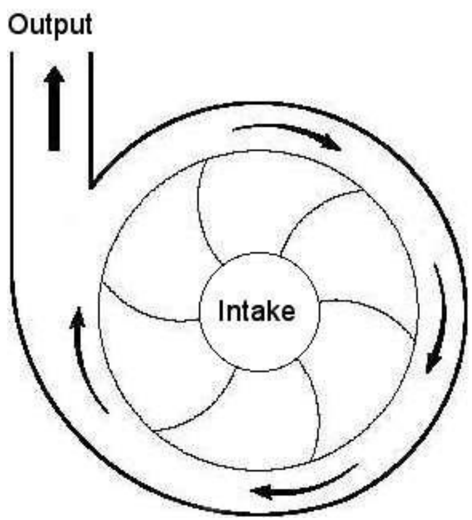


Fig. 5.3 : Vane type rotary air-com

Centrifugal compressor

- It is dynamic compressor.
- It consist of a rotating impeller which rotates at higher speed (upto 60000 rpm)
- An impeller fitted inside casing force the air to the rim of impeller, increasing velocity of air.

Centrifugal compressor



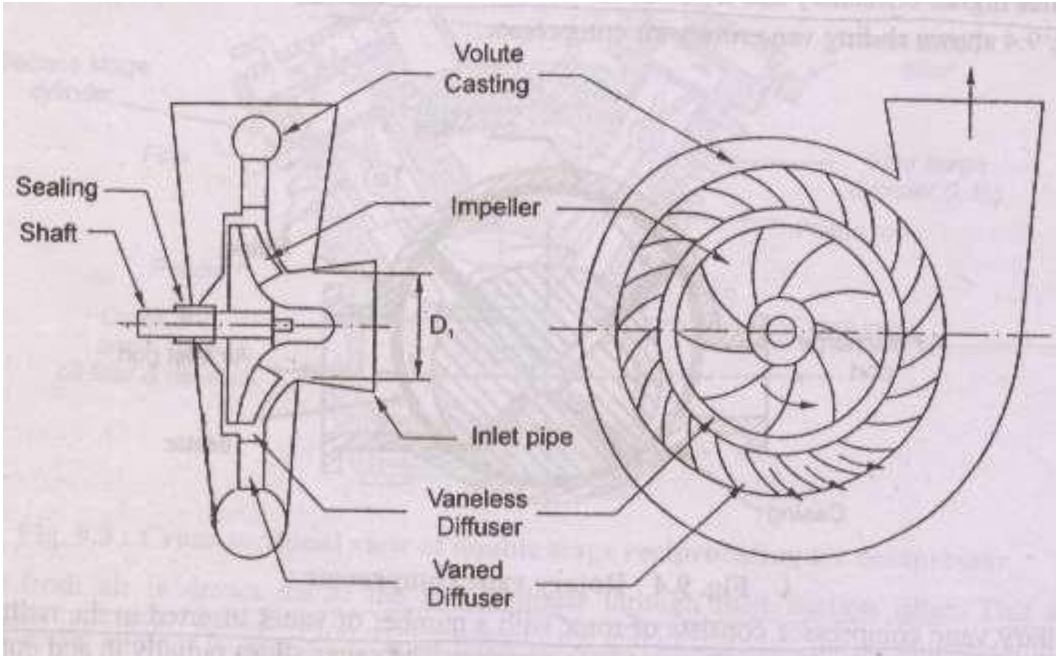


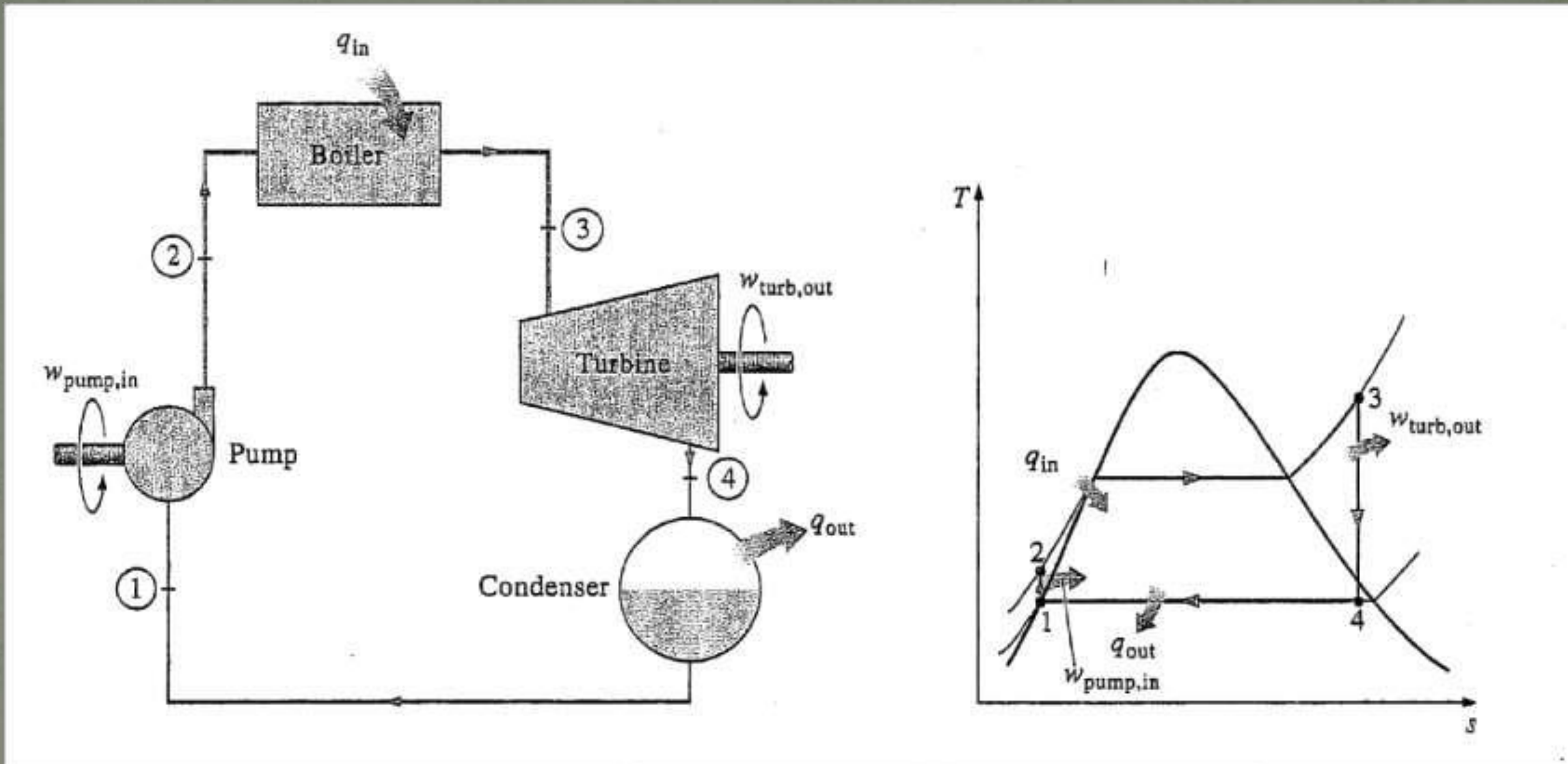
Fig. 9.5 : Centrifugal air compressor

Unit- III

RANKINE CYCLE

❖ *Principle*

- ***It works on the principle of heat engines which converts chemical energy of fuel in thermal energy for the generation of steam.***



- 1-2 isentropic pump
- 2-3 constant pressure heat addition
- 3-4 isentropic turbine
- 4-1 constant pressure heat rejection

❖ Efficiency

- $W_{net} = W_{turbine} - W_{pump}$
- Heat supplied = $Q_{in} - Q_{out}$
- Thermal efficiency,

$$\text{thermal efficiency} = \frac{\text{work done}}{\text{heat suppiled}}$$

$$h_{th} = W_{net} / Q_{in}$$

❖ Ideal Rankine Cycle

- *This cycle follows the idea of the Carnot cycle but can be practically implemented.*
- *1-2 isentropic pump*
- *2-3 constant pressure heat addition*
- *3-4 isentropic turbine*
- *4-1 constant pressure heat rejection*

Regenerative Cycle

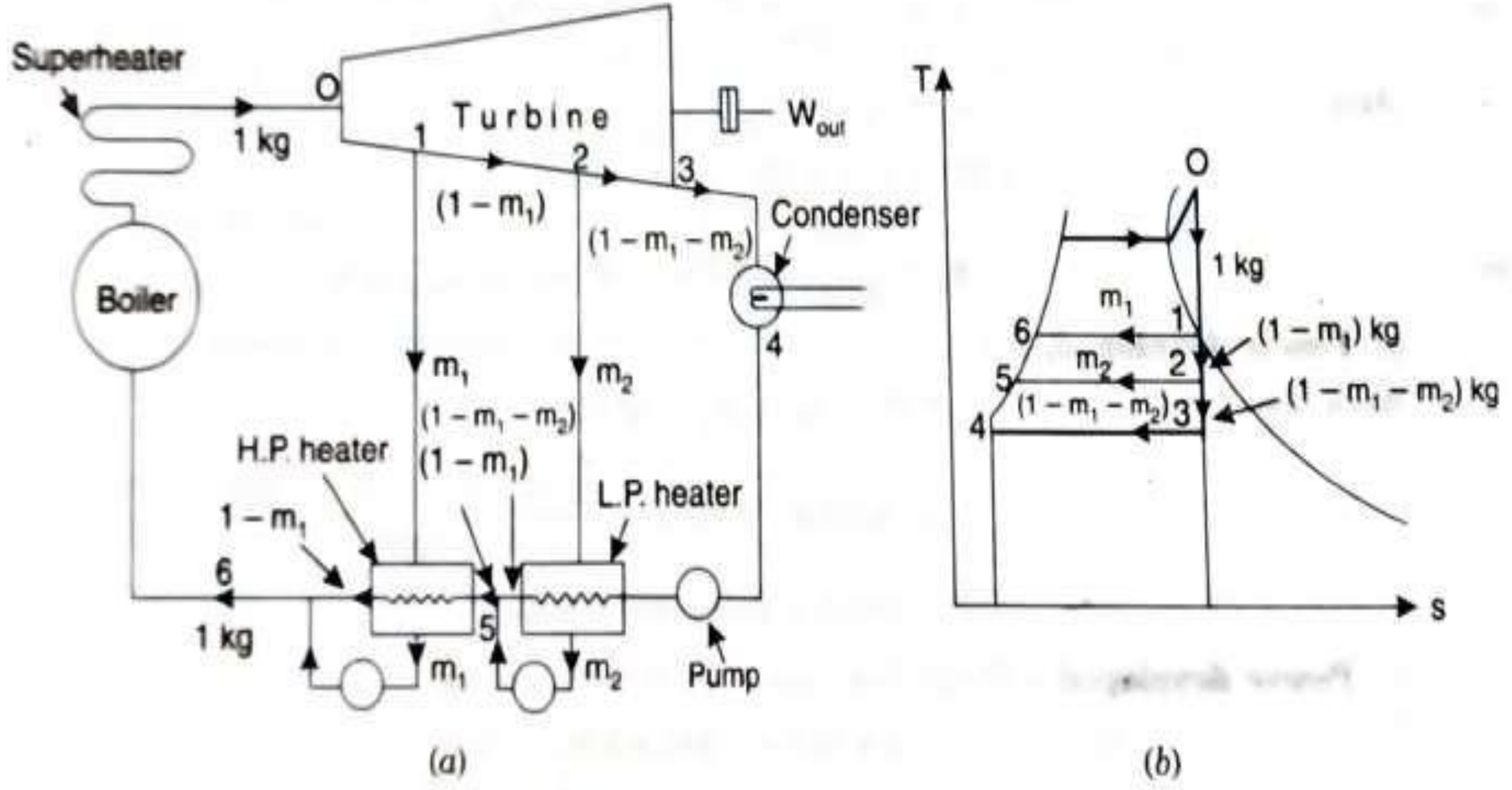


Fig. 15.15. Regenerative cycle.

Reheat Cycle

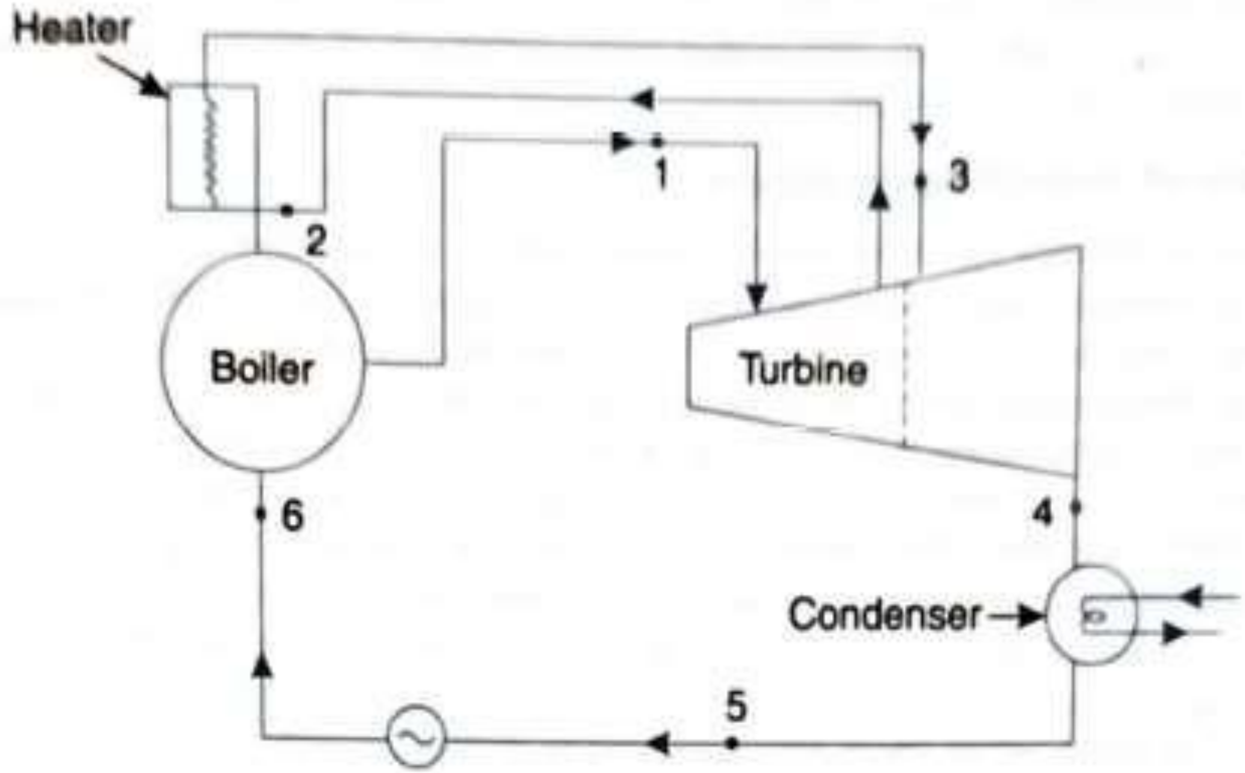
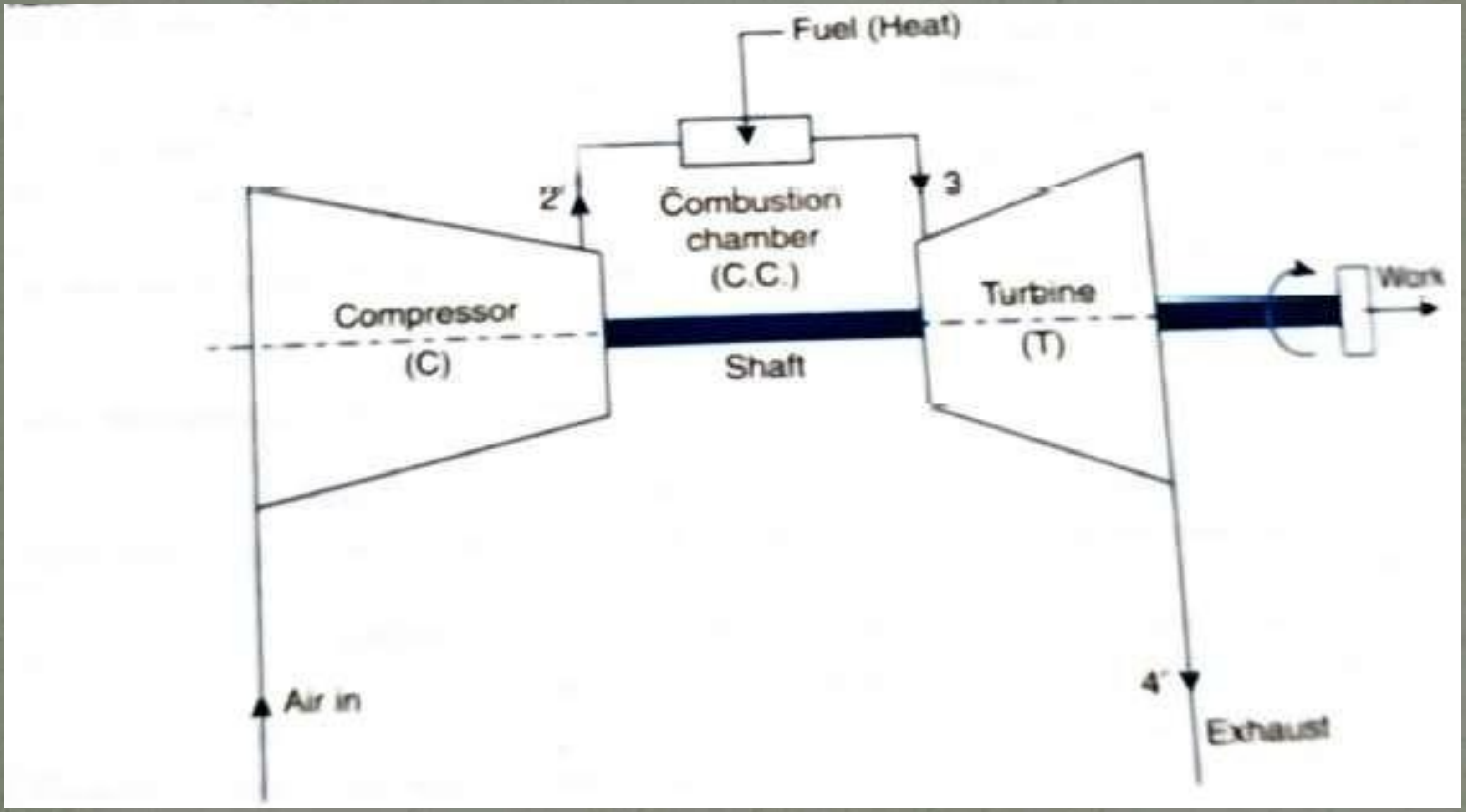
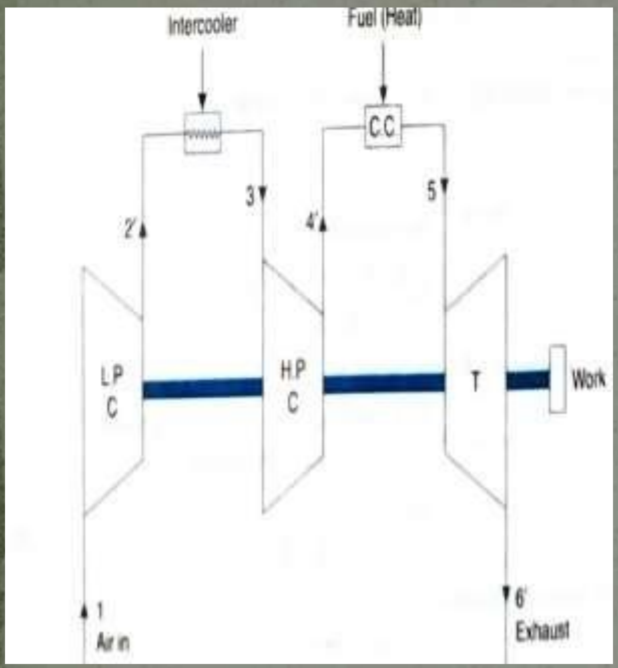


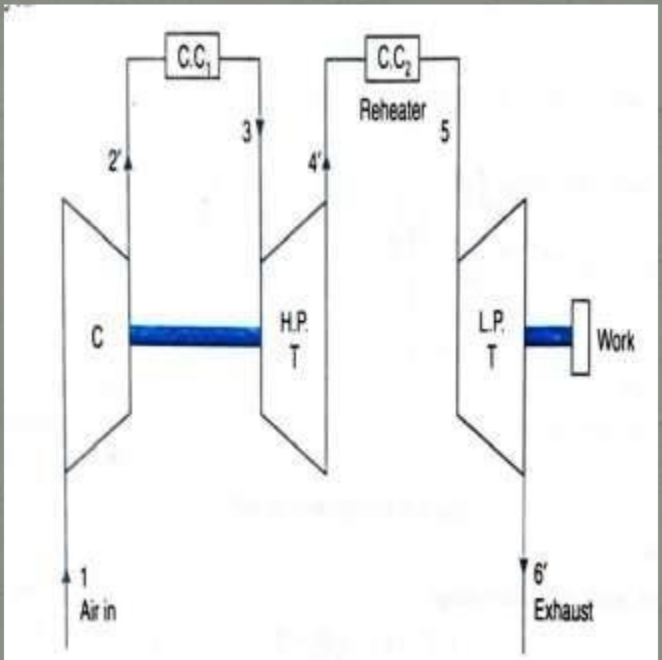
Fig. 15.24. Reheat cycle.

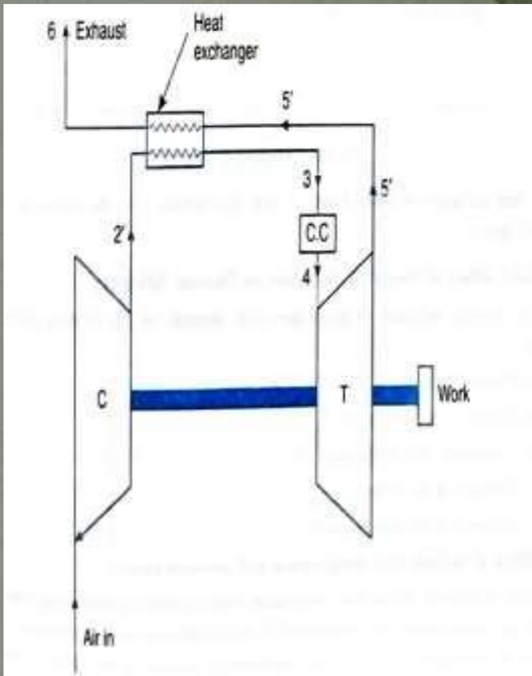
Gas turbines – Open type



Intercooling , Reheating & Regeneration







Unit IV – Steam Nozzles

- A steam nozzle is a passage of varying cross – section, which converts heat energy of steam into kinetic energy.
- During the first part of the nozzle, the steam increases in velocity. But later the steam gains more in volume than velocity.
- Since the mass of steam, passing through any section of the nozzle is constant the variation of steam pressure in nozzle depends on the velocity, specific volume , fraction of steam.
- A well designed nozzle produces a jet of steam with very high velocity.

Flow of steam through nozzles :

- The flow of steam through nozzles may be regarded as adiabatic expansion.

- The steam has a very high velocity at the end of the expansion, and the enthalpy decreases as expansion takes place.

- Friction exists between the steam and the sides of the nozzle; heat is produced as the result of the resistance to the flow.

- The phenomenon of supersaturation occurs in the flow of steam through nozzles. This is due to the time lag in the condensation of the steam during the expansion.

Continuity and steady flow energy equations

Through a certain section of the nozzle:

$m.v = A.C$

m is the mass flow rate, v is the specific volume, A is the cross-sectional area and C is the velocity.

For steady flow of steam through a certain apparatus, principle of conservation of energy states:

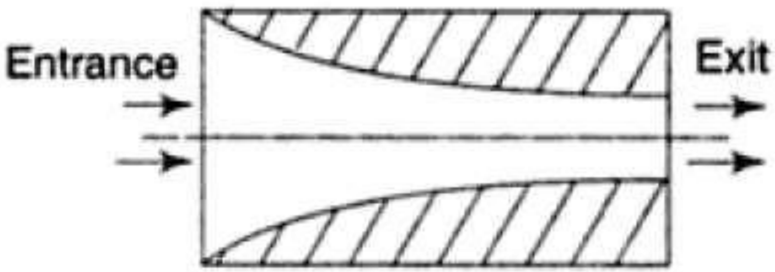
$$h_1 + C_1^2/2 + gz_1 + q = h_2 + C_2^2/2 + gz_2 + w$$

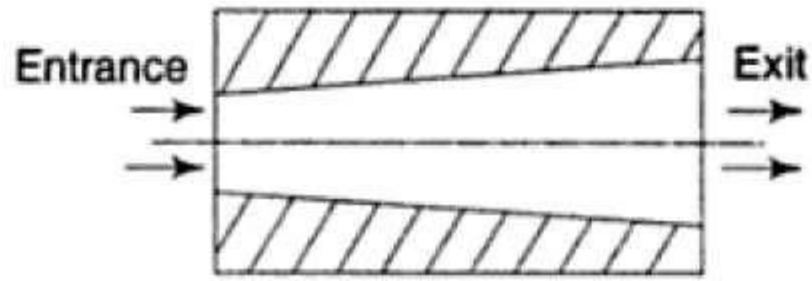
For nozzles, changes in potential energies are negligible, w = 0 and q ≅ 0.

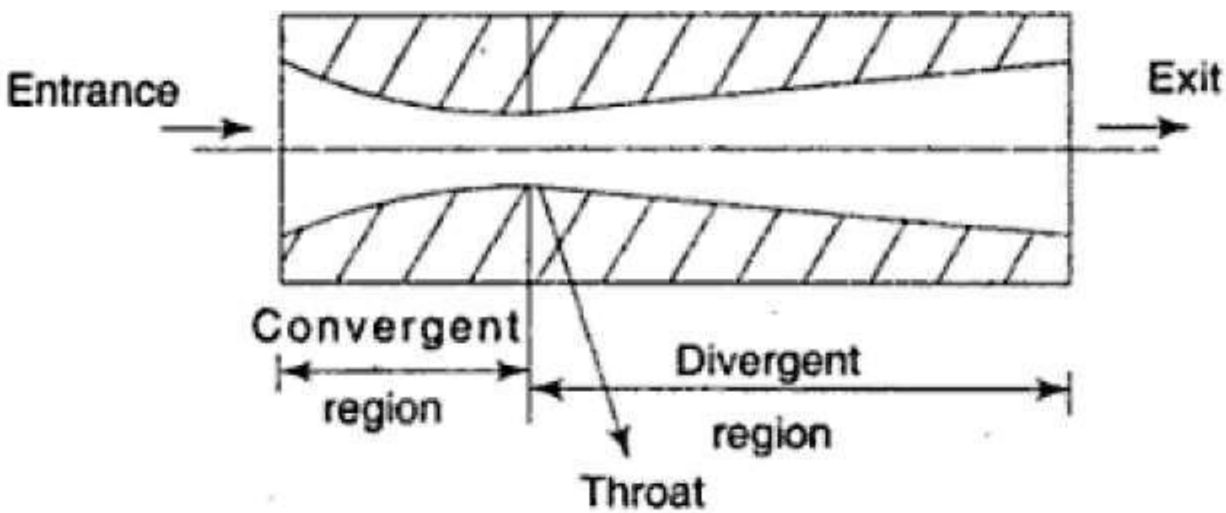
$$H_1 + C_1^2/2 = h_2 + C_2^2/2$$

Types of Nozzles:

1. Convergent Nozzle
2. Divergent Nozzle
3. Convergent-Divergent Nozzle







- The steam enters the nozzle with high pressure, but with negligible velocity. In the converging portion there is a drop in steam pressure with a rise in velocity. There is also a drop in enthalpy or total heat of steam.
- This drop in heat is also converted into kinetic energy.
- The steam leaves the nozzle with high velocity and small pressure. The pressure at which the steam leaves the nozzle is known as back pressure.
- There is no heat supplied or rejected in a nozzle. Hence the flow is considered to be isentropic and corresponding expansion is isentropic expansion.

Steam Turbines

- Steam turbine is a device which is used to convert kinetic energy of steam into mechanical energy.
- In this, enthalpy of steam is first converted into kinetic energy in nozzle or blade passages
- The high velocity steam impinges on the curved blades and its direction of flow is changed.
- This causes a change of momentum and thus force developed drives the turbine shaft
- The steam turbine has been used as a prime mover in all steam power plants.

- Now – a days, single steam turbine of 1000MW capacity is built in many countries.
- In large sizes, it is used for driving electric generator. In small sizes, it is used to drive pumps, fans, compressors
- Classification of steam turbines

Steam turbines are classified as follows

On the basis of method of steam expansion

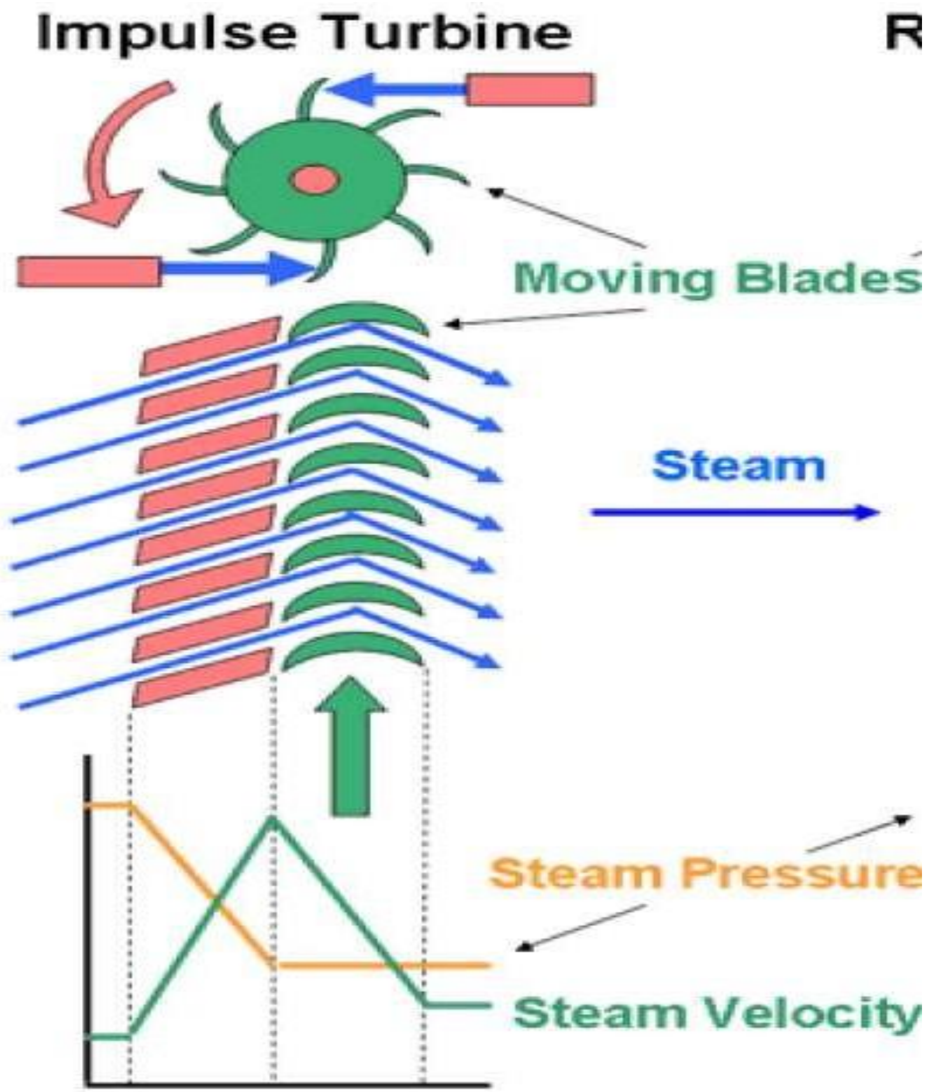
1) Impulse turbine, 2) Reaction turbine, 3) Combination of impulse and reaction turbine

On the basis of number of stages

1) Single stage 2) Multi - stage

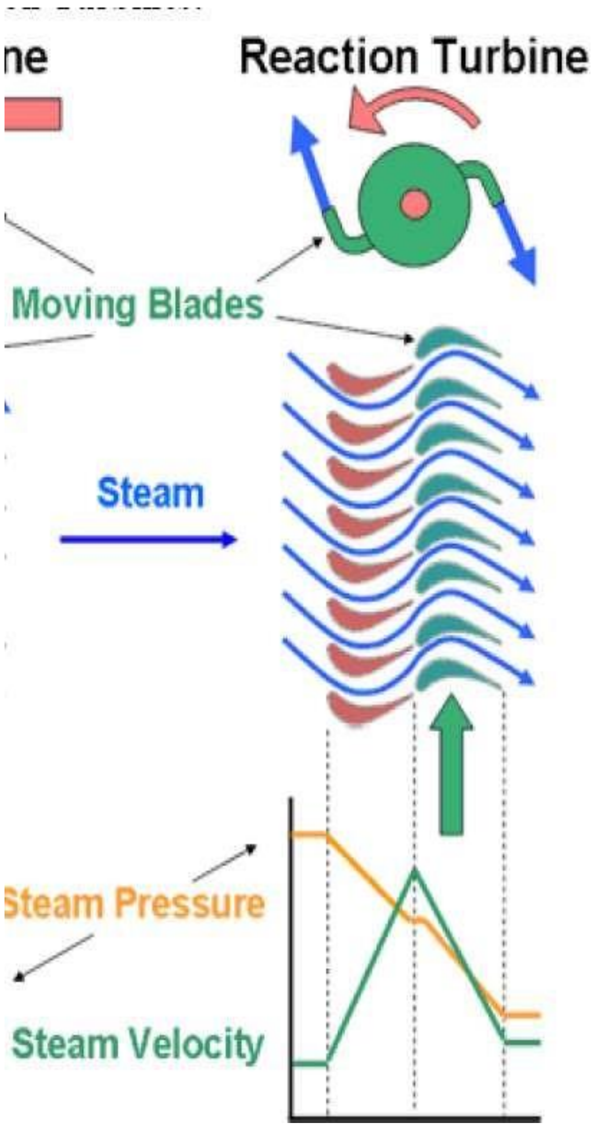
- On the basis of steam flow directions

Axial turbine 2)Radial turbine 3) Tangential turbine 4) Mixed flow



The steam jets are directed at the turbine's bucket shaped rotor blades where the pressure exerted by the jets causes the rotor to rotate and the velocity of the steam to reduce as it imparts its kinetic energy to the blades. The blades in turn change change the direction of flow of the steam however its pressure remains constant as it passes through the rotor blades since the cross section of the chamber between the blades is constant. Impulse turbines are therefore also known as constant pressure turbines.

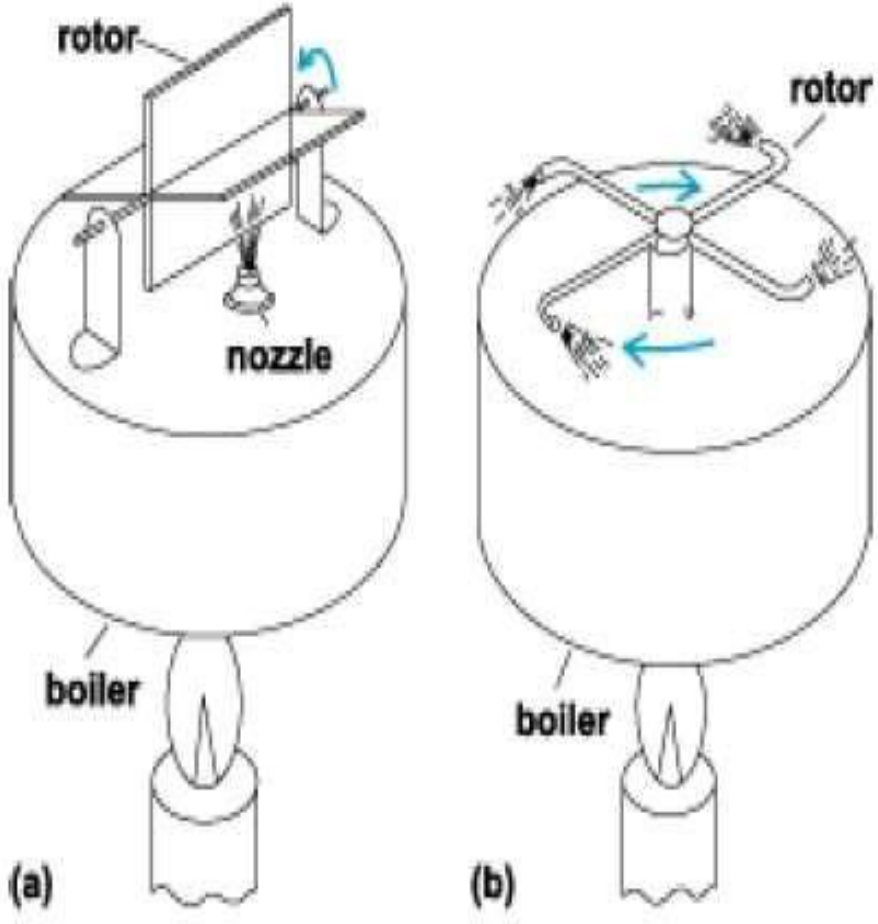
The next series of fixed blades reverses the direction of the steam before it passes to the second row of moving blades.



ne
Reaction Turbine
Moving Blades
Steam
Steam Pressure
Steam Velocity

- In reaction turbine there is no sudden pressure drop. There is a gradual pressure drop and takes place continuously over the fixed and moving blades.
- A number of moving blades are fitted to the rotating shaft. Fixed blades are provided in between such pairs of moving blades
- The function of fixed blades is that they guide the steam as well as allow it to expand in a larger velocity. It is similar to that of nozzles as in impulse turbine
- The moving blade serves the following functions
- It converts the kinetic energy into useful mechanical energy
- The steam expands in moving blades and gives reaction to the moving blades

The rotor blades of the reaction turbine are shaped more like aerofoils, arranged such that the cross section of the chambers formed between the fixed blades diminishes from the inlet side towards the exhaust side of the blades. The chambers between the rotor blades essentially form nozzles so that as the steam progresses through the chambers its velocity increases while at the same time its pressure decreases, just as in the nozzles formed by the fixed blades. Thus the pressure decreases in both the fixed and moving blades. As the steam emerges in a jet from between the rotor blades, it creates a reactive force on the blades which in turn creates the turning moment on the turbine rotor, just as in Hero's steam engine. (Newton's Third Law – For every action there is an equal and opposite reaction)


rotor
nozzle
boiler
(a)
rotor
boiler
(b)

Impulse Turbine	Reaction Turbine
It consists of nozzles and moving blades	It consists of fixed and moving blades
Pressure drop occurs in nozzles and not in moving blades	Pressure drop occurs in nozzles and moving blades
Steam strikes the blades with kinetic energy	Steam passes over the blades with pressure and kinetic energy
Blades are of symmetrical type	Blades are of varying cross section
Power developed is less	Power developed is more
It occupies less space for the same power	It occupies more space for the same power output
Velocity of turbine is high	Velocity of turbine is more
Efficiency is less	Efficiency is more
Blade manufacturing is simple as they are of symmetrical cross section	Blade manufacturing is difficult as it is of varying cross section

Compounding of turbines

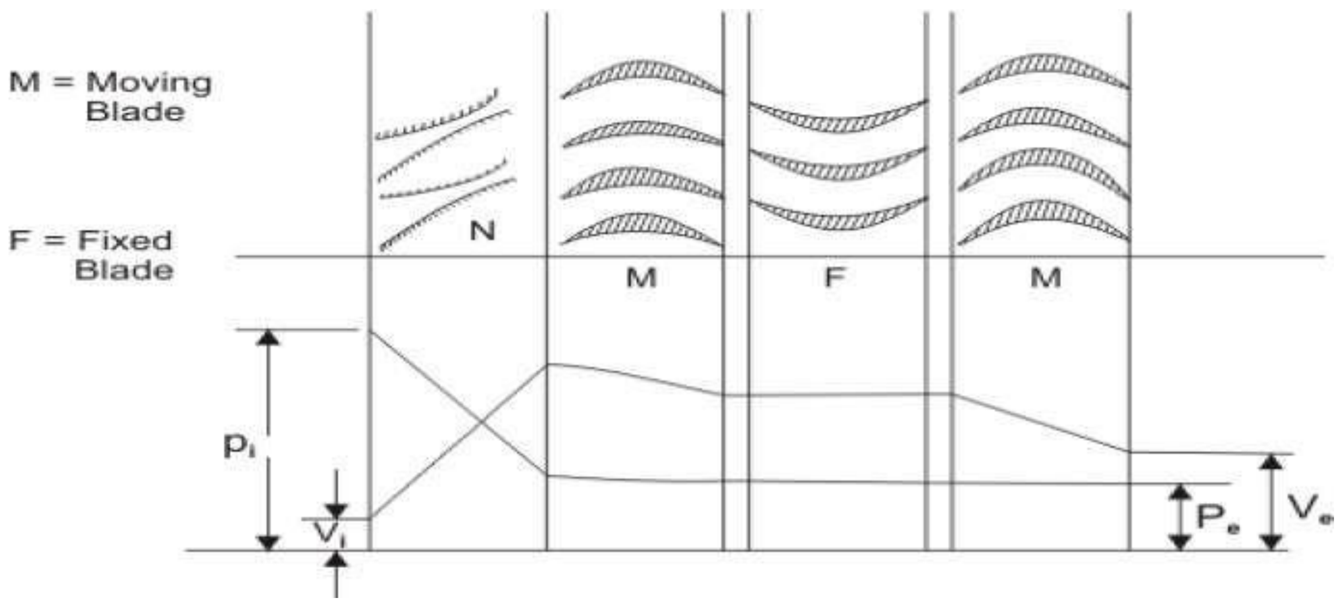
- If expansion of steam from boiler pressure to condenser pressure is carried out in a single stage impulse turbine i.e. in one nozzle and set of moving blades, the rotational speed of the rotor will be very high. Around 30000 RPM. This will cause damage to the rotating parts. Hence to prevent this ,the energy of steam is absorbed in stages. This is known as compounding of steam turbines.

- Compounding is achieved by using more than one set of nozzles, blades, rotors, in a series, keyed to a common shaft; so that either the steam pressure or the jet velocity is absorbed by the turbine in stages.

Types of compounding

- Velocity compounding
- Pressure compounding
- Pressure velocity compounding

Velocity Compounding



The velocity-compounded impulse turbine was first proposed by C.G. Curtis to solve the problems of a single-stage impulse turbine for use with high pressure and temperature steam. The Curtis stage turbine, as it came to be called, is composed of one stage of nozzles as the single-stage turbine, followed by two rows of moving blades instead of one. These two rows are separated by one row of fixed blades attached to the turbine stator, which has the function of redirecting the steam leaving the first row of moving blades to the second row of moving blades. A Curtis stage impulse turbine is shown in Fig. with schematic pressure and absolute steam-velocity changes through the stage. In the Curtis stage, the total enthalpy drop and hence pressure drop occur in the nozzles so that the pressure remains constant in all three rows of blades.

- Advantages

Initial cost is less

Less space is required

The system is highly reliable and easy to start

Disadvantages

Frictional losses are high due to high initial velocity. Hence efficiency is low

The ratio of blade velocity to steam velocity is not optimum for all wheels. It also reduces the efficiency

The power developed in last rows is only a fraction of the power developed in the first row. But, still the space requirement of all the stages is the same.

- Pressure Compounding

In this method, a number of simple impulse turbines are arranged in series.

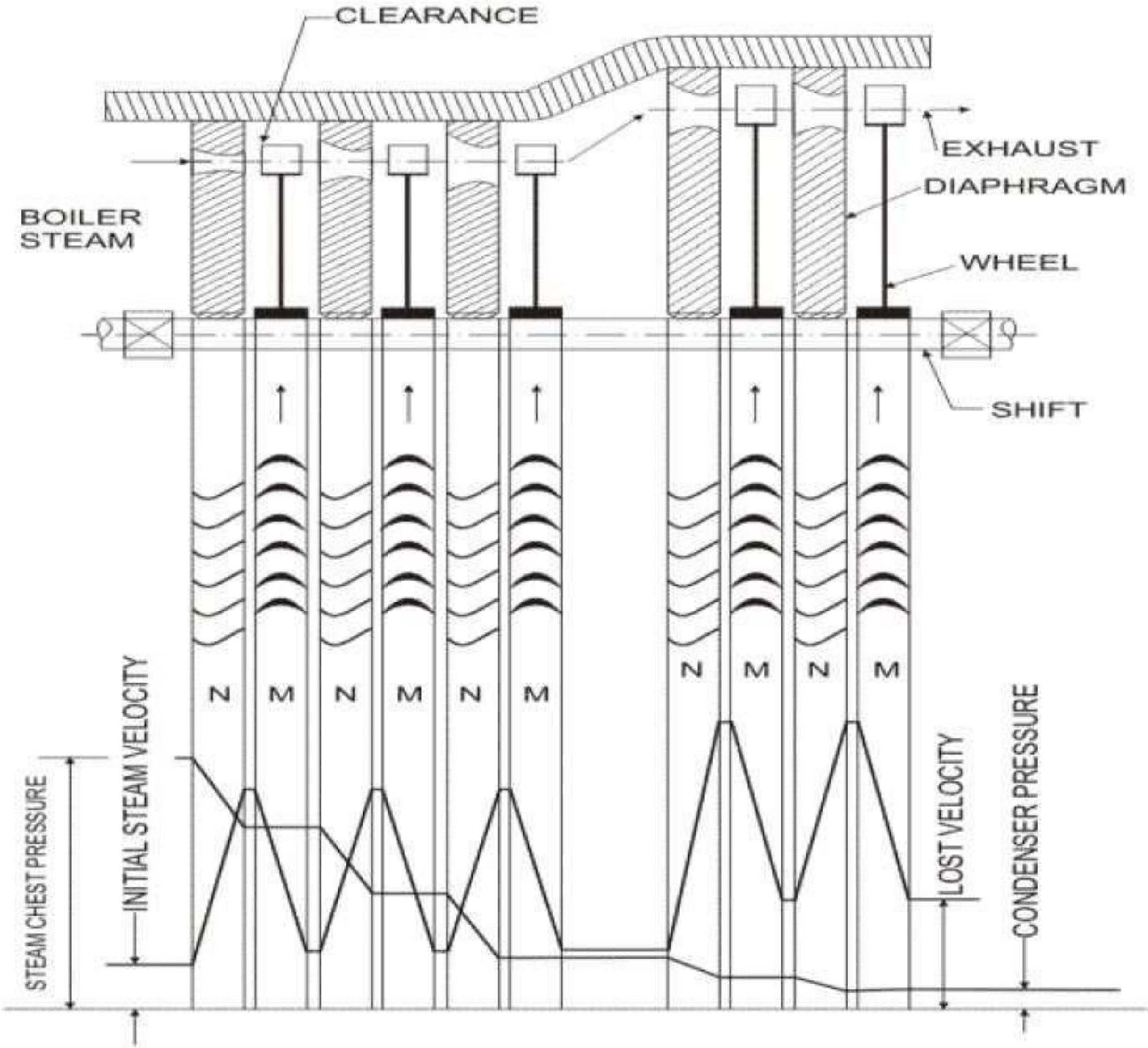
It consists of one set of nozzles and one row of moving blades.

The exhaust from each row of moving blades enters the succeeding set of nozzles

Velocity of steam increases when it passes through the nozzles and pressure drops.

Both velocity and pressure of steam decreases as it passes through moving blades

The pressure is reduced in each stage, hence it is called pressure compounding



CLEARANCE
EXHAUST
DIAPHRAGM
BOILER
STEAM
WHEEL
SHIFT
N
M
N
M
N
M
N
M
N
M
STEAM CHEST PRESSURE
INITIAL STEAM VELOCITY
LOST VELOCITY
CONDENSER PRESSURE

A two-row velocity compounded turbine is found to be more efficient than the three-row type. In a two-step pressure velocity compounded turbine, the first pressure drop occurs in the first set of nozzles, the resulting gain in the kinetic energy is absorbed successively in two rows of moving blades before the second pressure drop occurs in the second set of nozzles. Since the kinetic energy gained in each step is absorbed completely before the next pressure drop, the turbine is pressure compounded and as well as velocity compounded. The kinetic energy gained due to the second pressure drop in the second set of nozzles is absorbed successively in the two rows of moving blades. The pressure velocity compounded steam turbine is comparatively simple in construction and is much more compact than the pressure compounded turbine.

- Pressure Velocity Compounding

This method is a combination of pressure and velocity compounding.

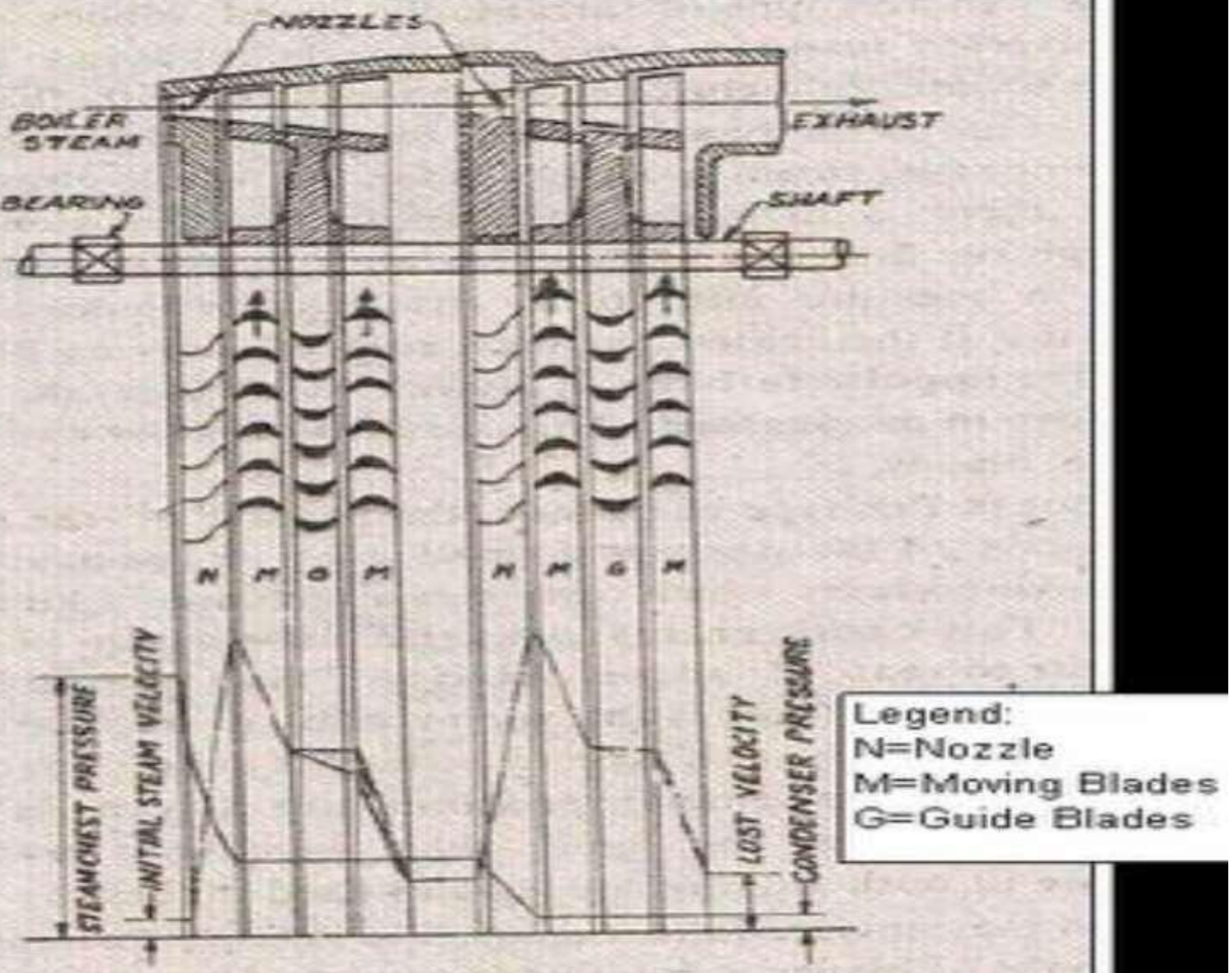
The total pressure drop is carried out inn two stages and velocity obtained in each stage is also compounded

Pressure is dropped in stages through nozzles

Velocity compounding is done by using a fixed blade between every two moving blades

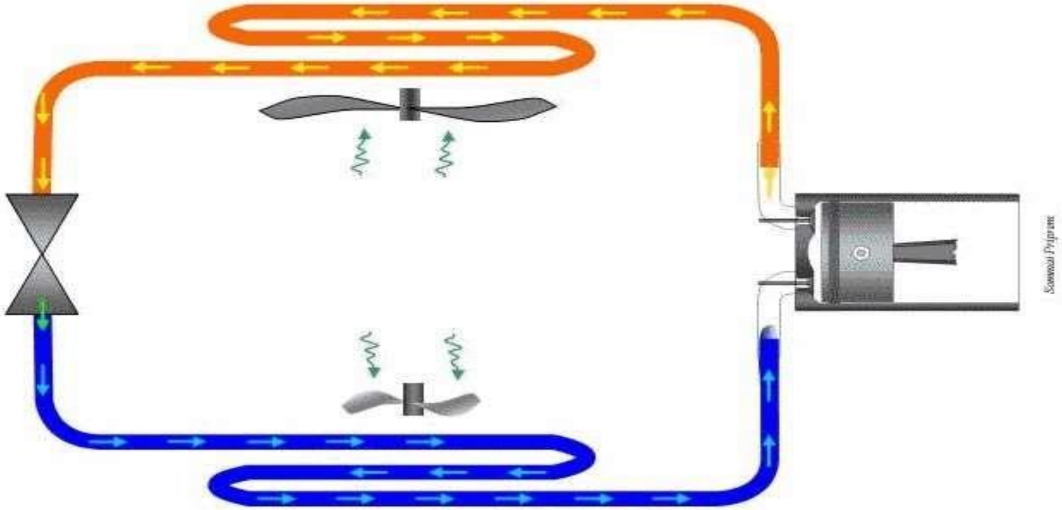
High pressure steam expands through first nozzles, enters the first row of moving blades. In the nozzle the pressure decreases and velocity increases. In the moving blades the velocity is converted into work but pressure remains constant

- Then steam enters the fixed blades and its direction changes. There is no change in velocity and pressure in the fixed blades. The steam then enters the second moving blades where the velocity is again converted into work.
- Then steam enters the second set of nozzles where pressure is again decreased and the process of doing work in two sets of moving blades with a guide blade is continued.
- Thus the total pressure drop is obtained in nozzle sets and velocity changes takes place through moving blades.
- This turbine combines the advantage of pressure and velocity compounding. Since there is a large pressure drop in each stage, less number of stages are used.
- This method is used in Curtis and Moore turbines.



Diagrammatic Arrangement of Pressure-Velocity Compounded Impulse Turbine.

REFRIGERATION AND AIR CONDITIONING



Refrigeration

- It is defined as the process of providing and maintaining a temperature well below that of surrounding atmosphere.
- In other words refrigeration is the process of cooling substance.

Terminologies of Refrigeration

Refrigerating Effect (N): It is defined as the quantity of heat extracted from a cold body or space to be cooled in a given time.

$$N = \frac{\text{Heat extracted from the cold space}}{\text{Time taken}}$$

Specific Heat of water and ice : It is the quantity of heat required to raise or lower the temperature of one kg of water (or ice), through one kelvin or (1^0 c) in one second.

Specific heat of water, C_{pw} = 4.19 kJ/kg K

Specific heat of ice, C_{pice} = 2.1 kJ/kg K.

Terminologies of Refrigeration

Capacity of a Refrigeration Unit :

- **Capacity of a refrigerating machines are expressed by their cooling capacity.**
- **The standard unit used for expressing the capacity of refrigerating machine is ton of refrigeration.**
- **One ton of refrigeration is defined as, "the quantity of heat abstracted (refrigerating effect) to freeze one ton of water into one ton of ice in a duration of 24 hours at 0^o c".**

Terminologies of Refrigeration

Co efficient of Performance: It is defined as the ratio of heat extracted in a given time (refrigerating effect) to the work input.

$$\text{Co efficient of performance} = \frac{\text{Heat extracted in evaporator}}{\text{Work Input}}$$

$$\text{Co efficient of performance} = \frac{\text{Refrigerating Effect}}{\text{Work Input}}$$

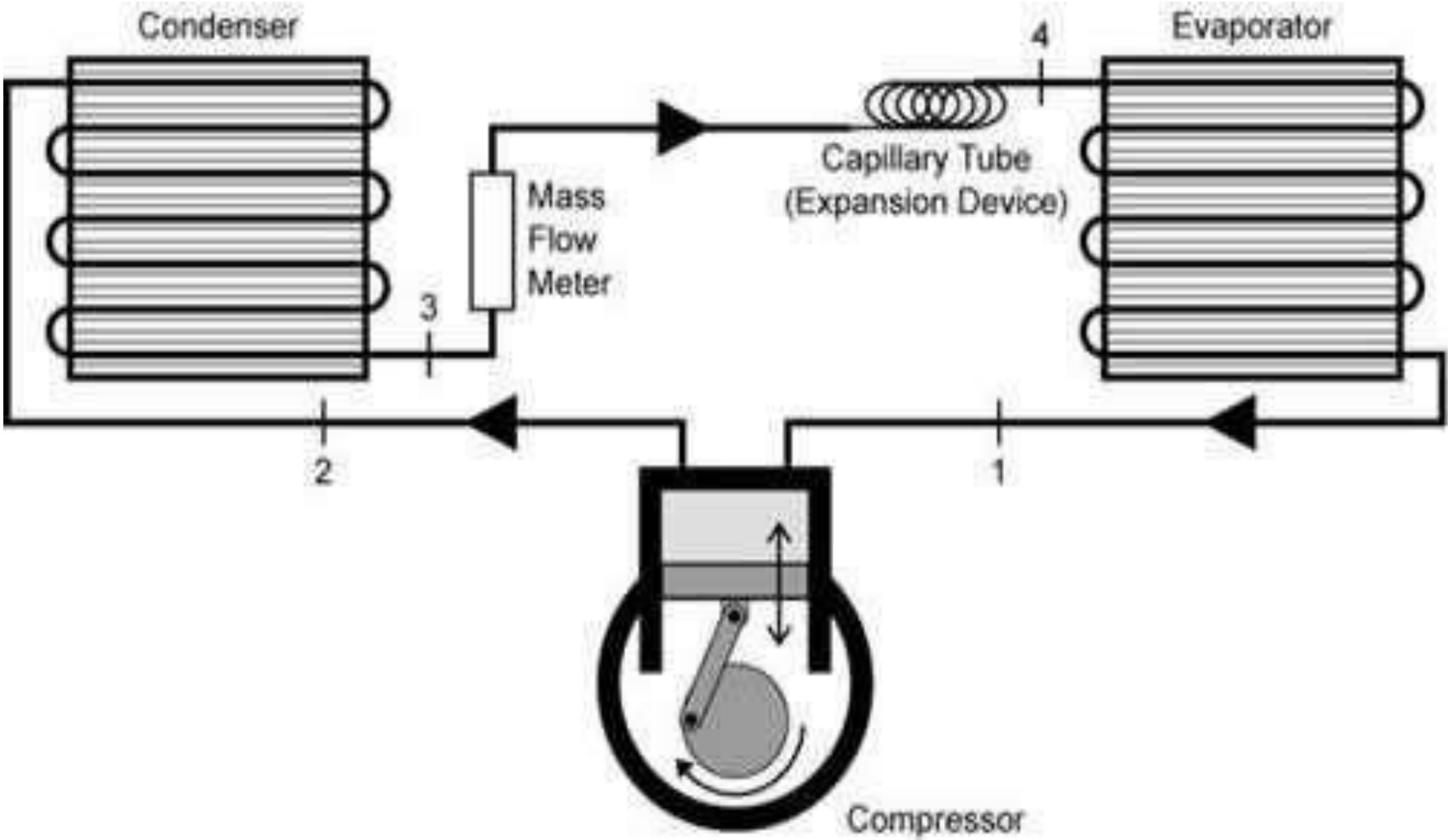
$$\text{Co efficient of performance} = \frac{N}{W}$$

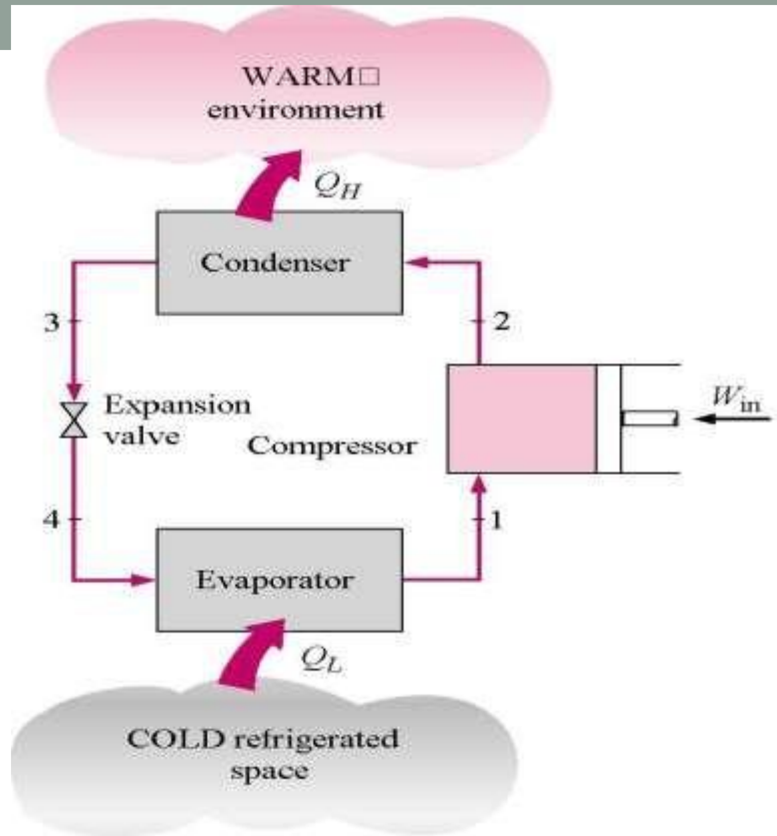
The COP is always greater than 1 for VCR system and known as theoretical coefficient of performance.

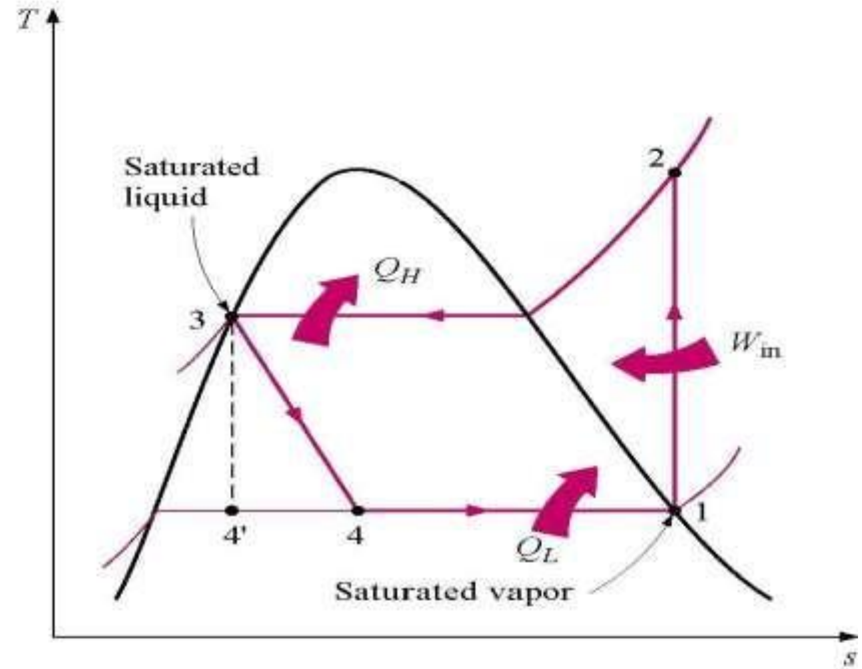
Applications of Refrigeration

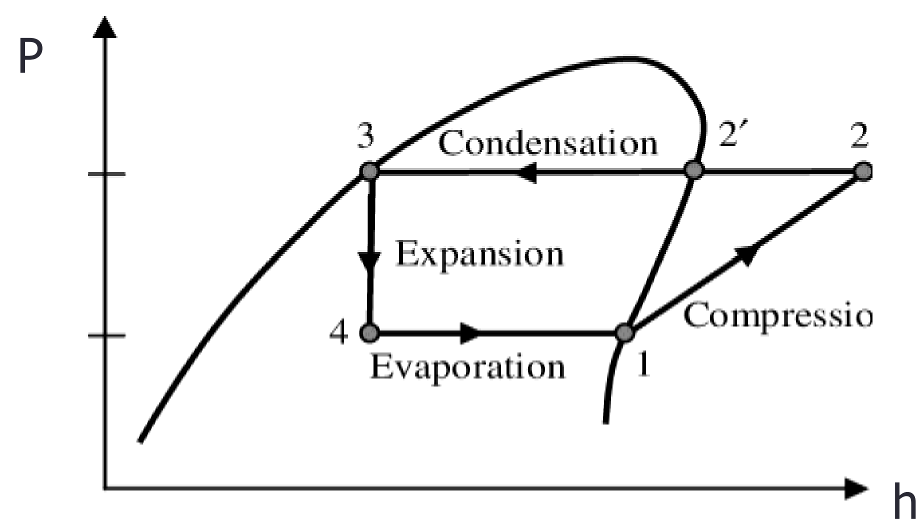
- In chemical industries, for separating and liquefying the gases.
- In manufacturing and storing ice.
- For the preservation of perishable food items in cold storages.
- For cooling water.
- For controlling humidity of air manufacture and heat treatment of steels.
- For chilling the oil to remove wax in oil refineries.
- For the preservation of tablets and medicines in pharmaceutical industries.
- For the preservation of blood tissues etc.,
- For comfort air conditioning the hospitals, theatres, etc.,

Vapour Compression Refrigeration System




WARM□ environment
Q_H
Condenser
3
2
Expansion valve
Compressor
W_{in}
4
1
Evaporator
Q_L
COLD refrigerated space


T
Saturated liquid
2
Q_H
3
W_{in}
4'
4
1
Q_L
Saturated vapor
s


P
3
Condensation
2′
2
Expansion
Compressio
4
Evaporation
1
h

Refrigerants

Refrigerant: **Any substance that absorbs heat through expansion and vaporisation process and loses heat due to condensation is a refrigeration process is called refrigerant.**

Some examples of refrigerants are,

- *Air*
- *Ammonia (NH_3)*
- *Carbon dioxide (CO_2)*
- *Sulphur dioxide (SO_2)*
- *Freon – 12*
- *Methyl Chloride*
- *Methylene chloride.*

Selecting Refrigerants

- ►Refrigerant selection is based on several factors:
  - ►Performance: provides adequate cooling capacity cost-effectively.
  - ►Safety: avoids hazards (i.e., toxicity).
  - ►Environmental impact: minimizes harm to stratospheric ozone layer and reduces negative impact to global climate change.

Vapour Absorption Refrigeration system

In this system compression process of vapour compression cycle is eliminated. Instead of that the following three processes are carried out.

1. *Absorbing ammonia vapour into water.*
2. *Pumping this solution to a high pressure cycle*
3. *Producing ammonia vapours from ammonia solution by heating.*

Vapour Absorption Refrigeration system - Construction

Construction:

- The vapour absorption system consists of a condenser, an expansion valve and an evaporator.
- They perform the same as they do in vapour compression method.
- In addition to these, this system has an absorber, a heat exchanger, an analyser and a rectifier.

Comparison between Vapour compression & Vapour Absorption refrigeration systems

S.No.	Vapour Compression System	Vapour Absorption System
1	This system has more wear and tear and produces more noise due to the moving parts of the compressor.	Only moving part in this system is an aqua pump. Hence the quieter in operation and less wear and tear
2.	Electric power is needed to drive the system	Waste of exhaust steam may be used. No need of electric power
3.	COP is more	COP is less
4.	At partial loads performance is poor.	At partial loads performance is not affected.
5.	Mechanical energy is supplied through compressor	Heat energy is utilised
6.	Energy supplied is ¼ to ½ of the refrigerating effect (less)	Energy supplied is about one and half times the refrigerating effect (more)

Comparison between Vapour compression & Vapour Absorption refrigeration systems

S.No.	Vapour Compression System	Vapour Absorption System
7.	Charging of the refrigerating to the system is easy	Charging of refrigerant is difficult
8.	Preventive measure is needed, since liquid refrigerant accumulated in the cylinder may damage to the cylinder	Liquid refrigerant has no bad effect on the system.

AIR CONDITIONING

AIR CONDITIONING:

Air Conditioning is the process of conditioning the air according to the human comfort, irrespective of external conditions.

AIR CONDITIONING

Applications of Air Conditioning

- Used in offices, hotels, buses, cars.,etc
- Used in industries having tool room machines.
- Used in textile industries to control moisture.
- Used in printing press.
- Used in Food industries, Chemical plants.

CLASSIFICATION OF AIR CONDITIONING

Air conditioning systems are classified as

1) According to the purpose
   a) Comfort Air conditioning.
   b) Industrial Air conditioning.
2) According to Season of the year
   a) Summer Air conditioning.
   b) Winter Air conditioning.
   c) Year round Air conditioning.

TERMINOLOGIES

1) Dry air: The atmospheric air which no water vapour is called dry air.

2) Psychrometry: Psychrometry is the study of the properties of atmospheric air.

3) Temperature: The degree of hotness (or) Coldness is called the temperature.

4) Moisture: Moisture is the water vapour present in the air.

TERMINOLOGIES

Humidity: mass of water vapor present in 1kg of dry air

Absolute humidity: mass of water vapor present in 1cu.m of dry air

5) Relative humidity: Relative humidity is the ratio of actual mass of water vapour in a given volume to the mass of water vapour actually can withhold by the same volume.

6) Dry bulb temperature: The temperature of air measured by the ordinary thermometer is called dry bulb temperature:

TERMINOLOGIES

7) Wet bulb Temperature: The temperature of air measured by the thermometer when it is covered by the wet cloth is known as wet bulb Temperature.

8) Dew point Temperature:The temperature at which the water vapour starts condensing is called dew pointTemperature

9) Wet bulb depression: (DBT- WBT) indicates relative humidity

10) Dew point depression: (DBT- DPT)