# UNIT - II

## Chapter – 4

# Thermal Engineering 1: Prime movers

## Session 4: Steam Turbines

# Topic Learning Outcomes:

**1. Discuss Steam as a working medium in prime movers and heat engines and its characteristic properties**

**2. Explain the working principle of impulse and reaction steam turbine**

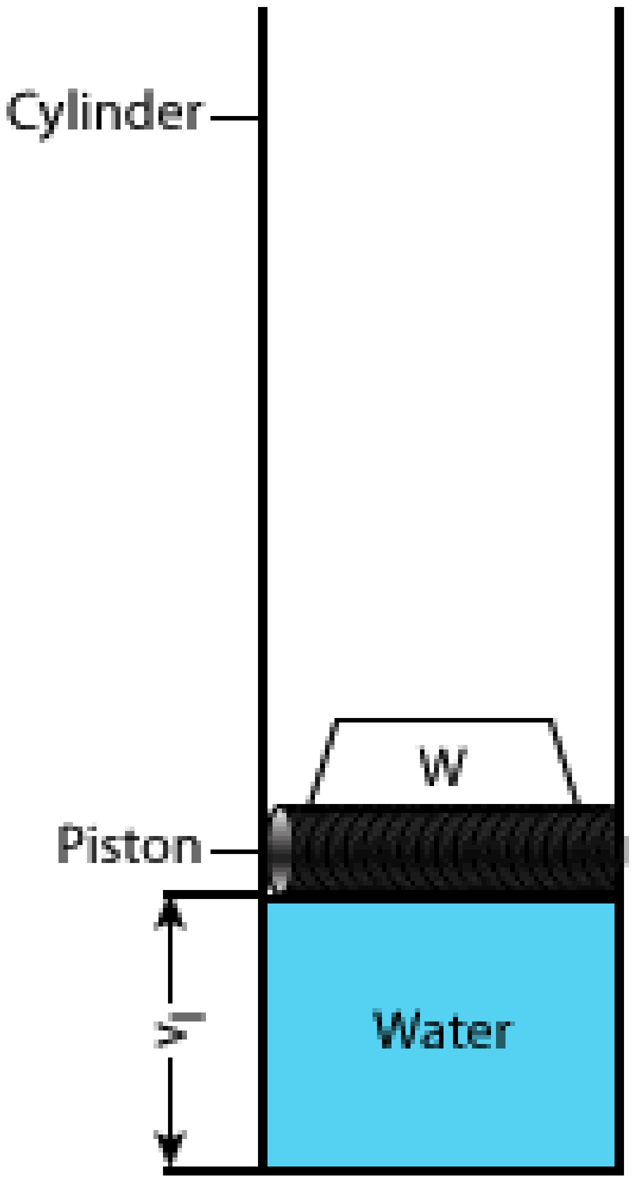
3. Outline the basic operating principles behind two-stroke and four-stroke internal combustion engines.

# Lesson Schedule

| |
|---|
| 1.1. Introduction, classification and parts of an IC Engine |
| 1.2. Working principle of 4 stroke petrol and diesel Engine |
| 2.1. Working principle of 2 stroke petrol and diesel Engine |
| 2.2. Comparison of 2 stroke and 4 stroke engine, Comparison of diesel and petrol engine |
| 3.1. Numerical problems on engine performance |
| **4.1. Steam- Formation of steam, Properties of steam** |
| **4.2. Applications of steam, Steam turbines:**<br>**Working principle of impulse and reaction steam turbines** |

# Formation of steam at constant pressure

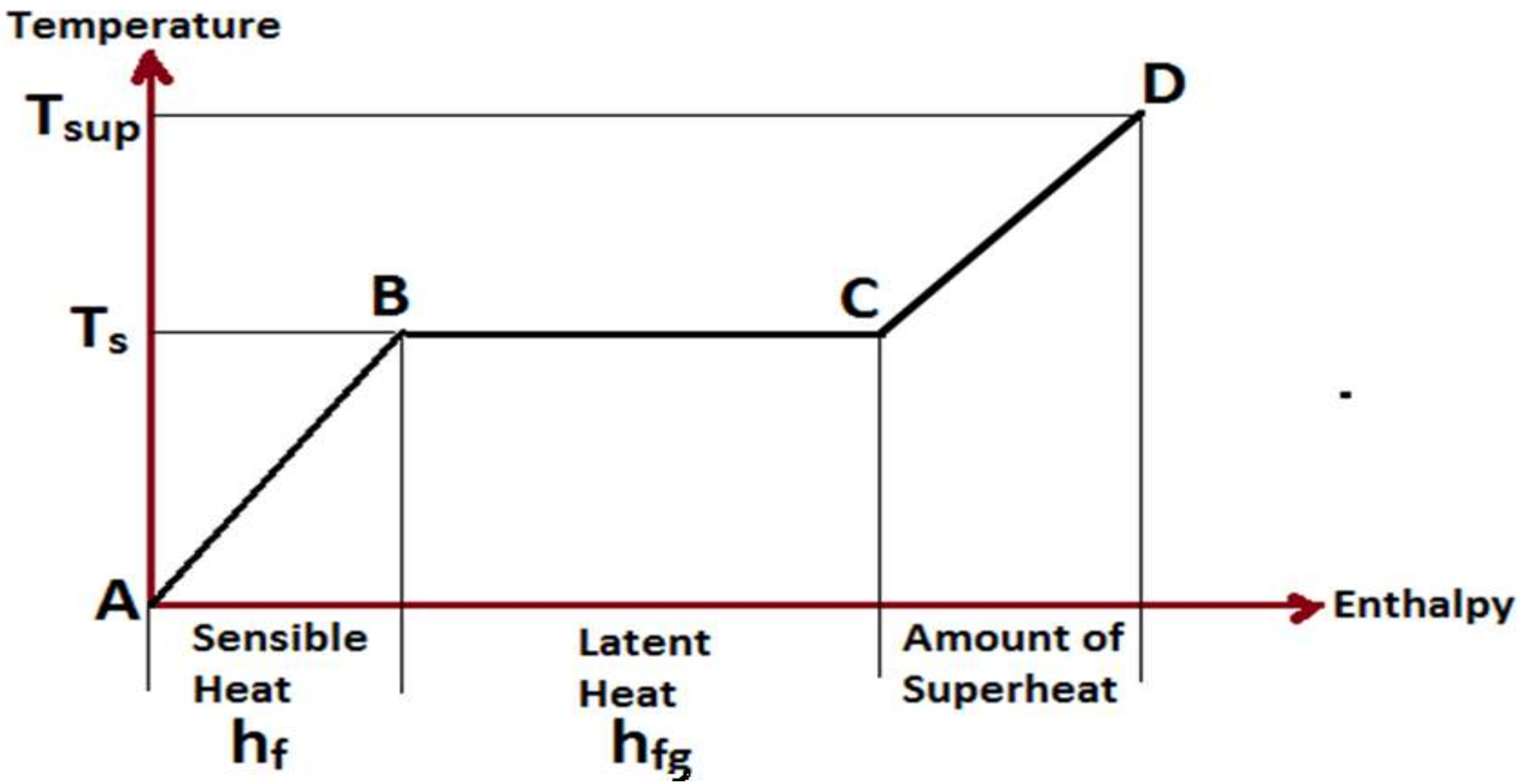
- To know the various properties of steam, at a particular pressure, an experiment is conducted.
- 1 kg of water at $0^0$ C is taken in a cylinder, with a movable piston.
- A chosen weight is placed over the piston.
- Both piston & weight exerts constant pressure on water.
- This condition is represented by point **A** on t-h diagram.



# Temperature vs Enthalpy diagram (t-h diagram)

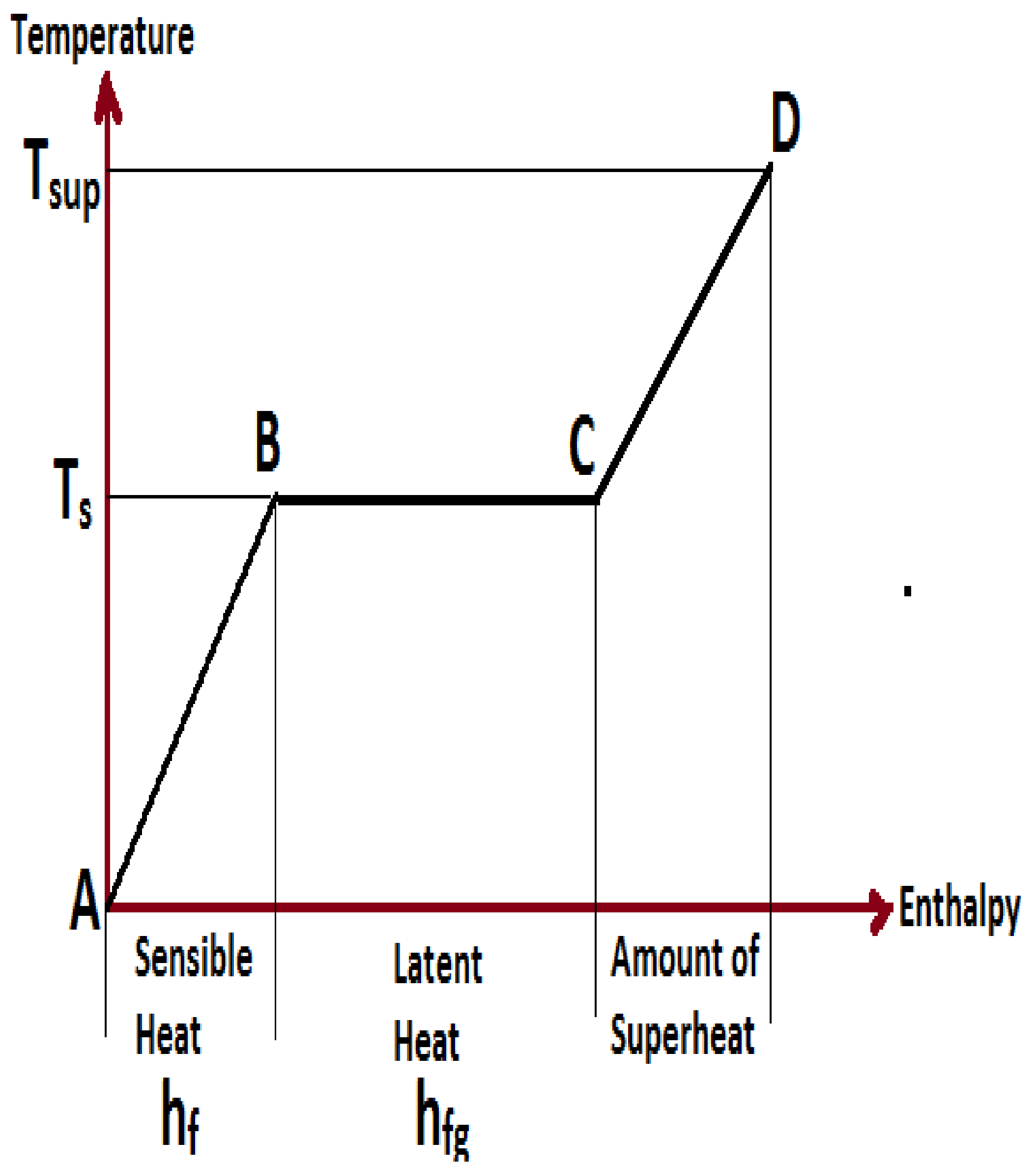
- Graphical representation, showing the various stages of formation of steam,

  → Starting from 1 kg of ice in to 1 kg of superheated steam.



# Formation of steam at constant pressure

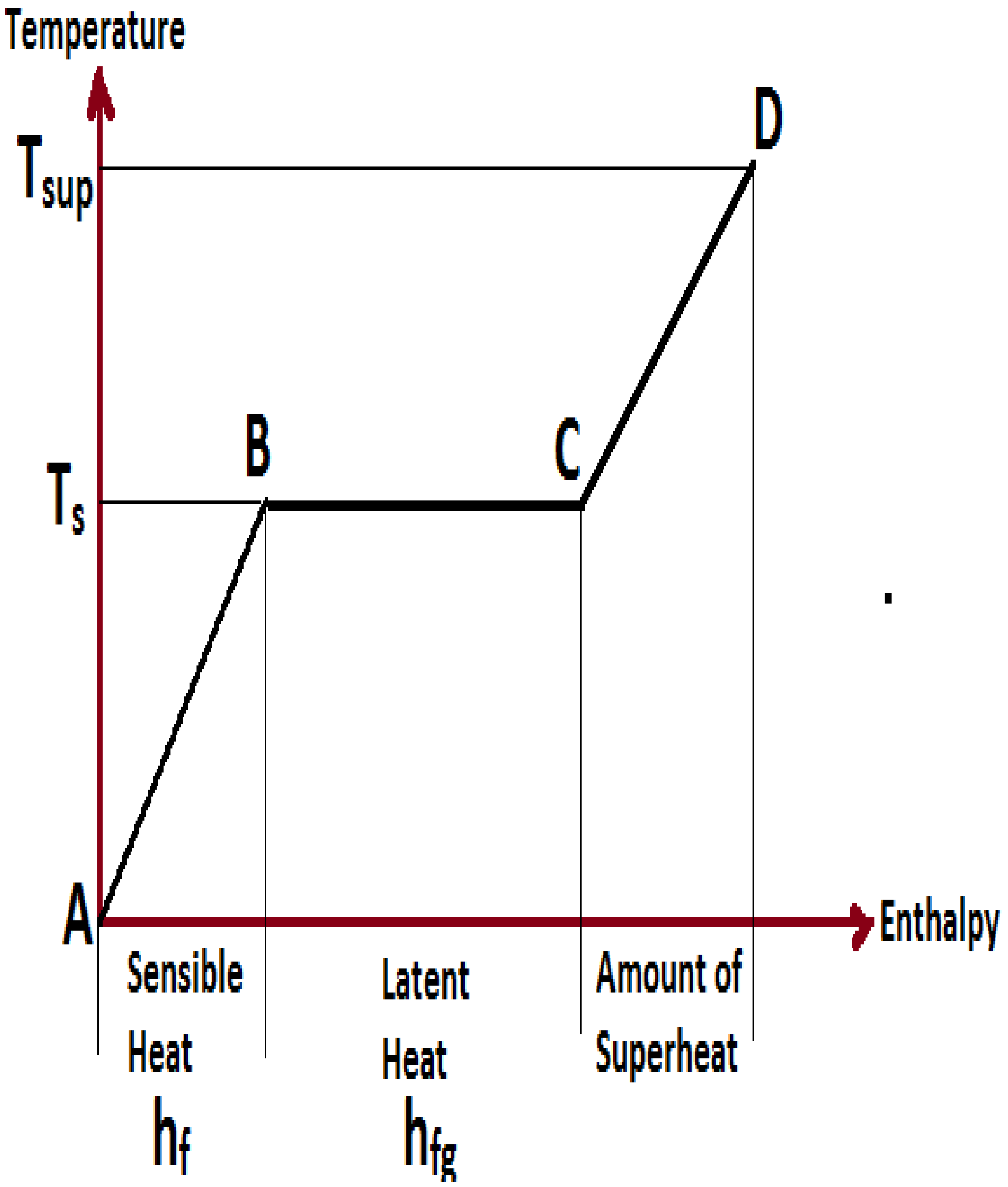
- Water is heated at constant pressure.
- Water temperature rises till its boiling point (saturation temperature- $T_s$).
- Slight increase in volume is observed.
- This condition is represented by point **B** on t-h diagram.



# Formation of steam at constant pressure

**Sensible heat ($h_f$) :**

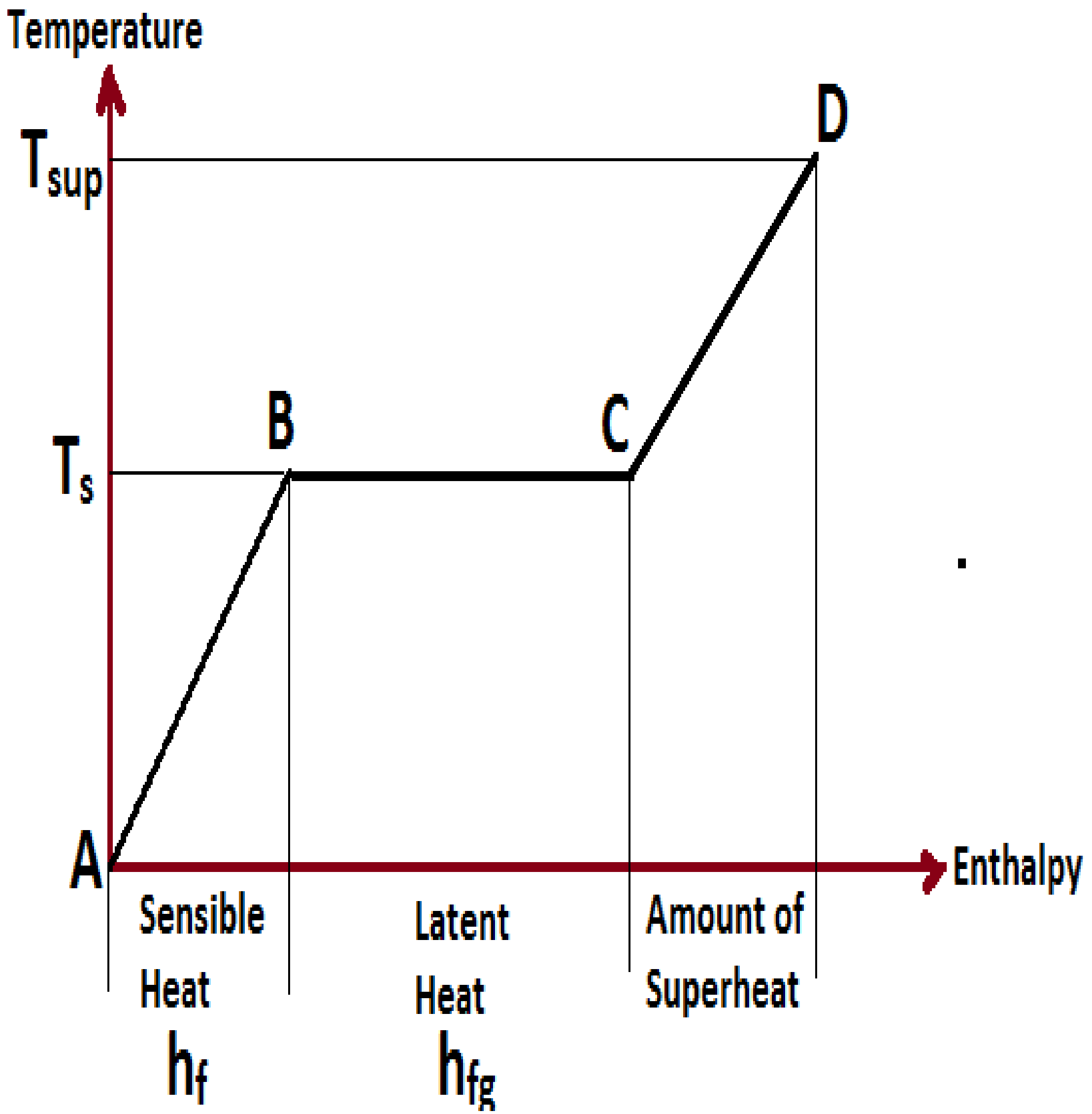
- Amount of heat required to raise the temperature of 1 kg of water from 0 $^0$C to the saturation temperature $T_s$ $^0$C, at a given constant pressure.



# Formation of steam at constant pressure

- Further addition of heat, initiates evaporation of water, while temperature remains same ($T_s$).

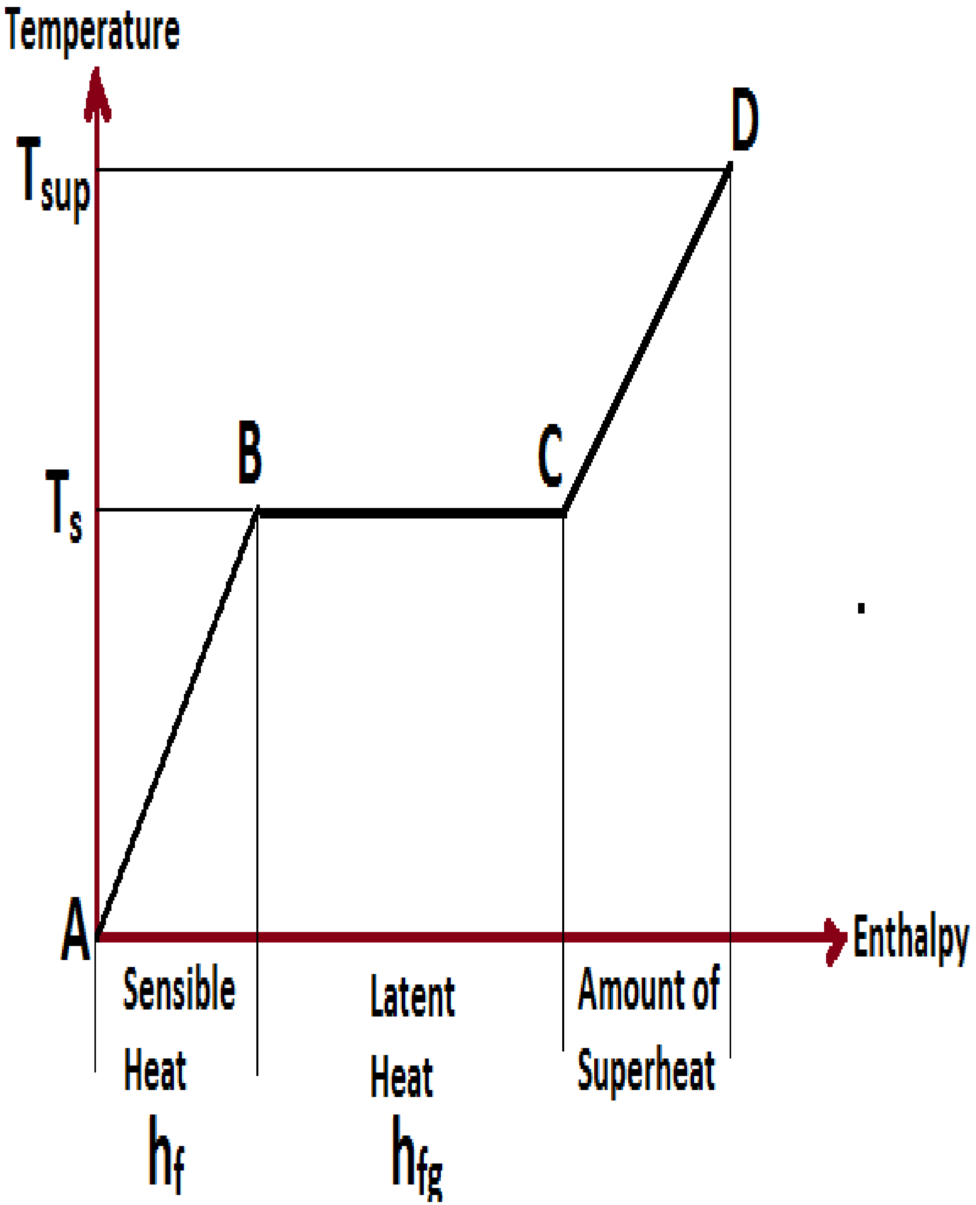
- Point **C** on graph represents the complete conversion of water in to gaseous phase (dry steam).



# Formation of steam at constant pressure

**Latent heat of evaporation or Enthalpy of evaporation ($h_{fg}$) :**

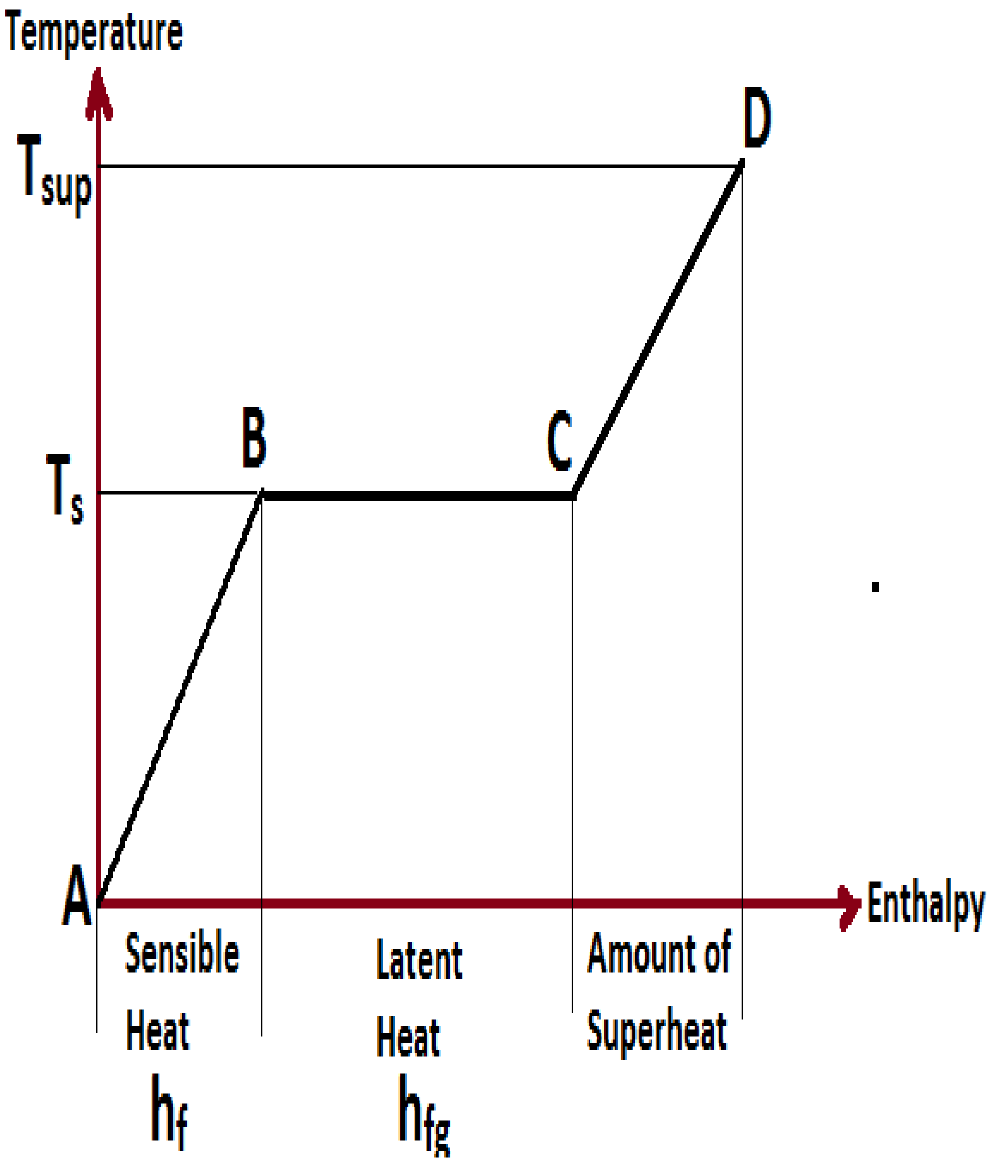
- Amount of heat required to evaporate 1 kg of water at saturation temperature Ts $^0$C, to 1 kg of dry steam at the same saturation temperature at given constant pressure.



# Formation of steam at constant pressure

- Further addition of heat at same constant pressure, increases the temperature above saturated temperature ($T_s$), known as superheated temperature ($T_{sup}$).

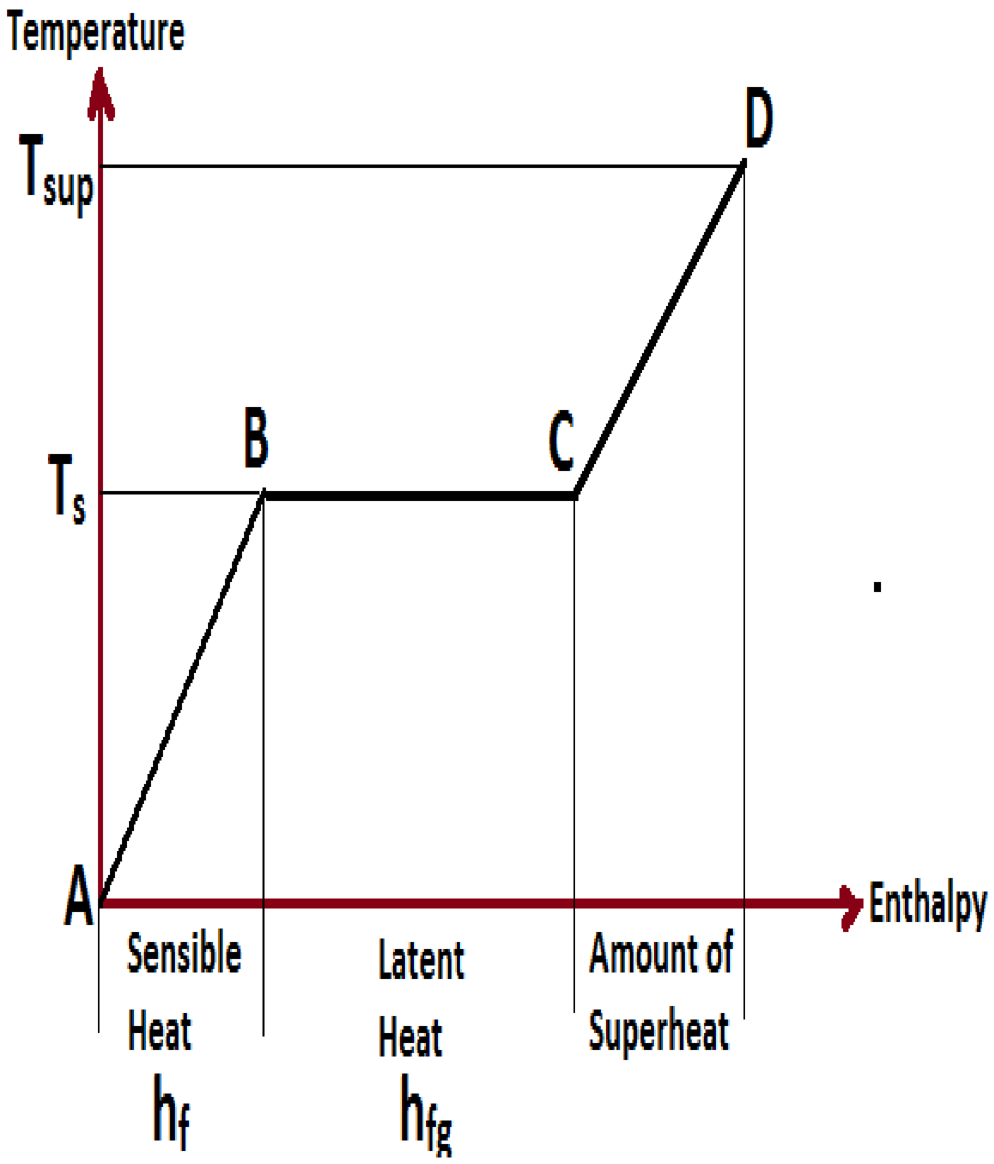
- This process of heating dry steam is known as **superheating**.



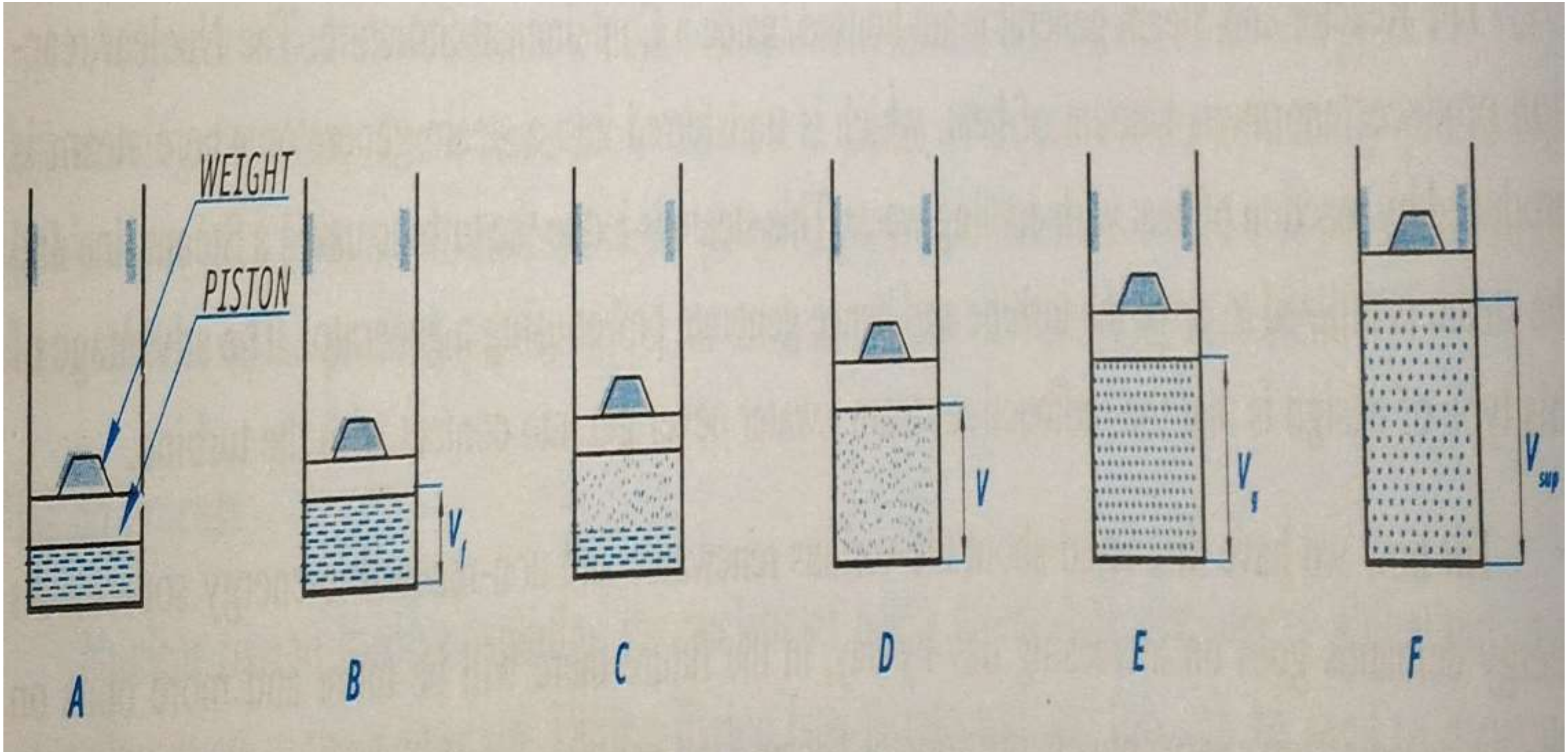
# Formation of steam at constant pressure

**Amount of superheat or**
**Enthalpy of superheat:**

- Amount of heat required to increase the temperature of dry steam from its saturation temperature, to any desired higher temperature at the given constant pressure.



# Formation of steam at constant pressure

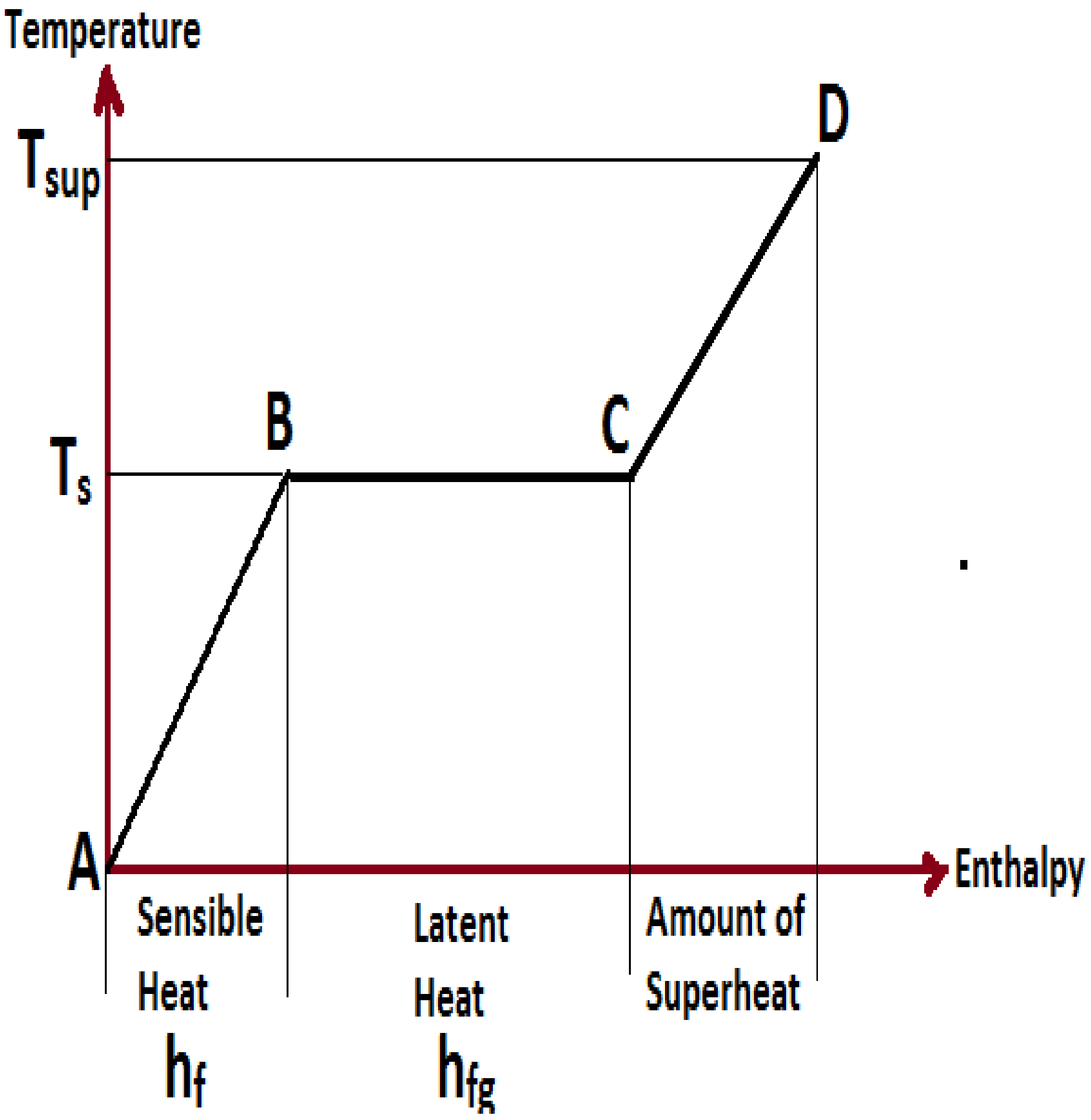


Formation of Steam

# Formation of steam at constant pressure

## Wet steam:

- It is defined as a two-phase mixture of water and steam in thermal equilibrium at the saturation temperature corresponding to a given pressure.



# Different states of steam

**Dry saturated steam or Dry steam:**

It is a saturated steam at the saturation temperature corresponding to a given pressure and having no water molecules entrained in it .

**Superheated steam:**

It is defined as the steam which is heated beyond its dry saturated state to temperatures higher than its saturated temperature at the given pressure.

# Steam Turbines

- It is a prime mover.
- Converts heat energy of steam, in to mechanical energy, in the form of rotary motion.
- The heat energy is first converted into kinetic(velocity) energy which in turn is transformed into mechanical energy of rotation.

**Applications:**

- To generate electrical energy
- To propel the ships
- Centrifugal compressors
- Textile and Sugar Industries

# STEAM Turbines

## Classification

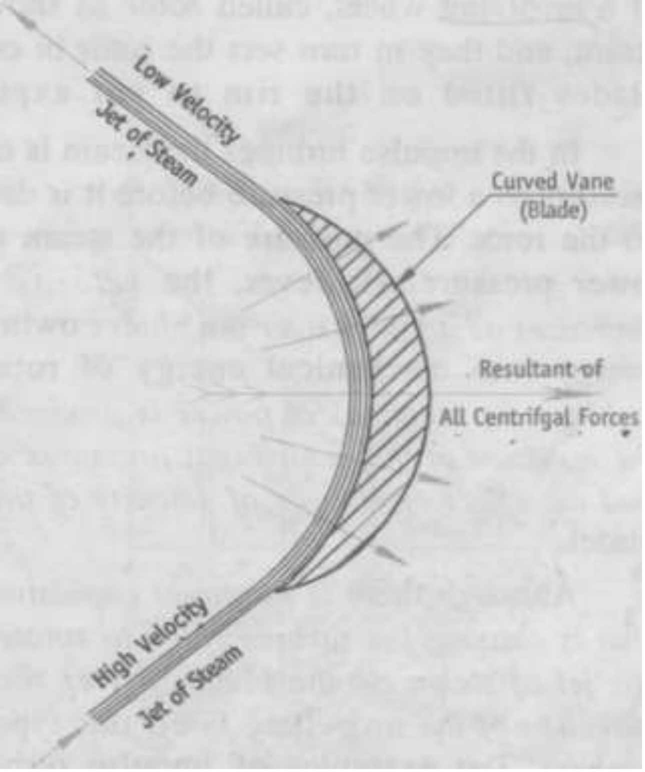
1. **Impulse Turbine**

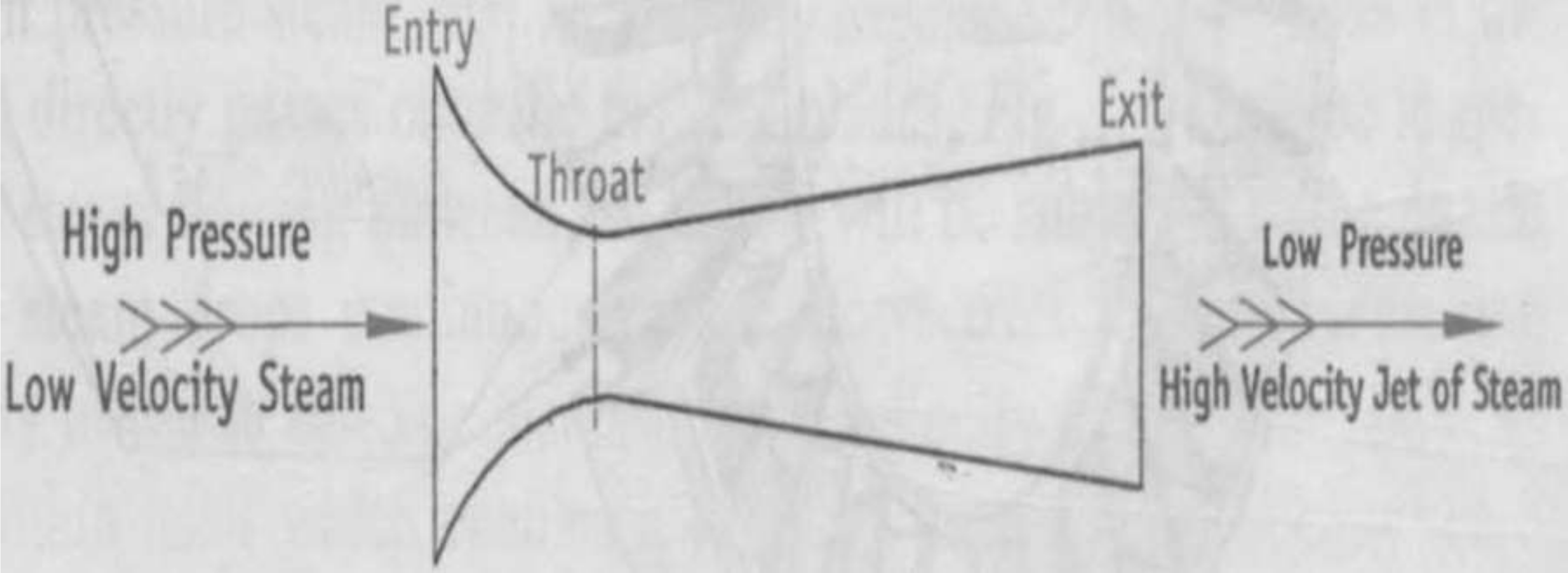
2. **Reaction Turbine**

# Impulse Steam turbine

In this type of turbine, the steam is initially expanded in a nozzle from high pressure to low pressure.

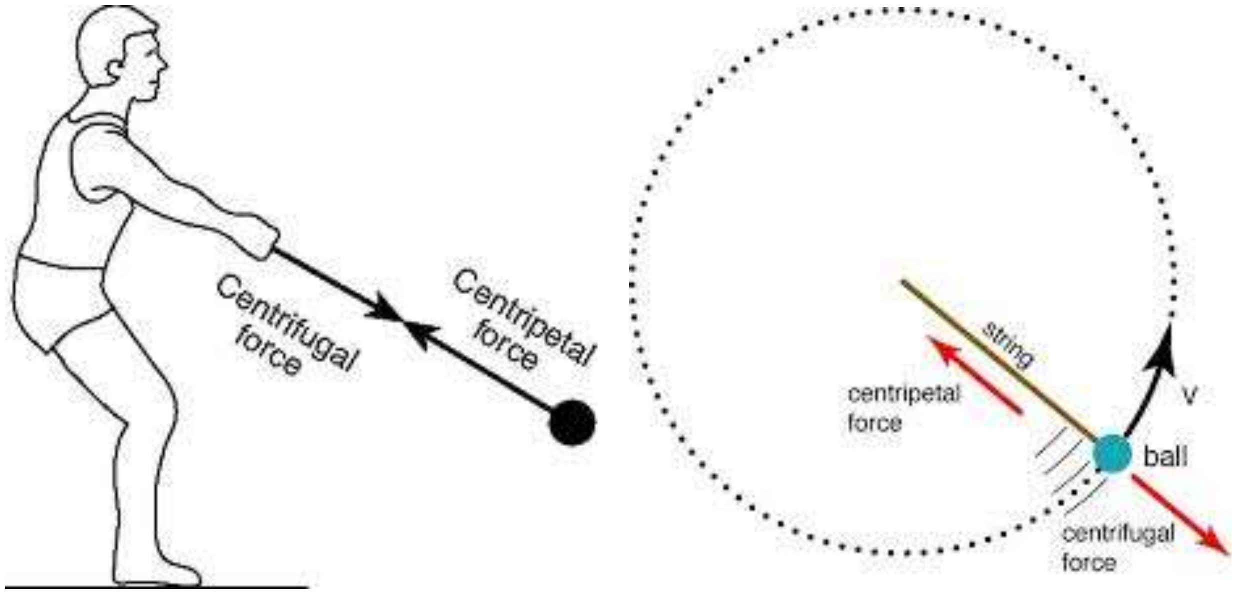
The high velocity jet of steam coming out of the nozzle is made to glide over a curved vane, called blade.



The jet of steam gliding over the blade gets deflected very nearly in the circumferential direction.

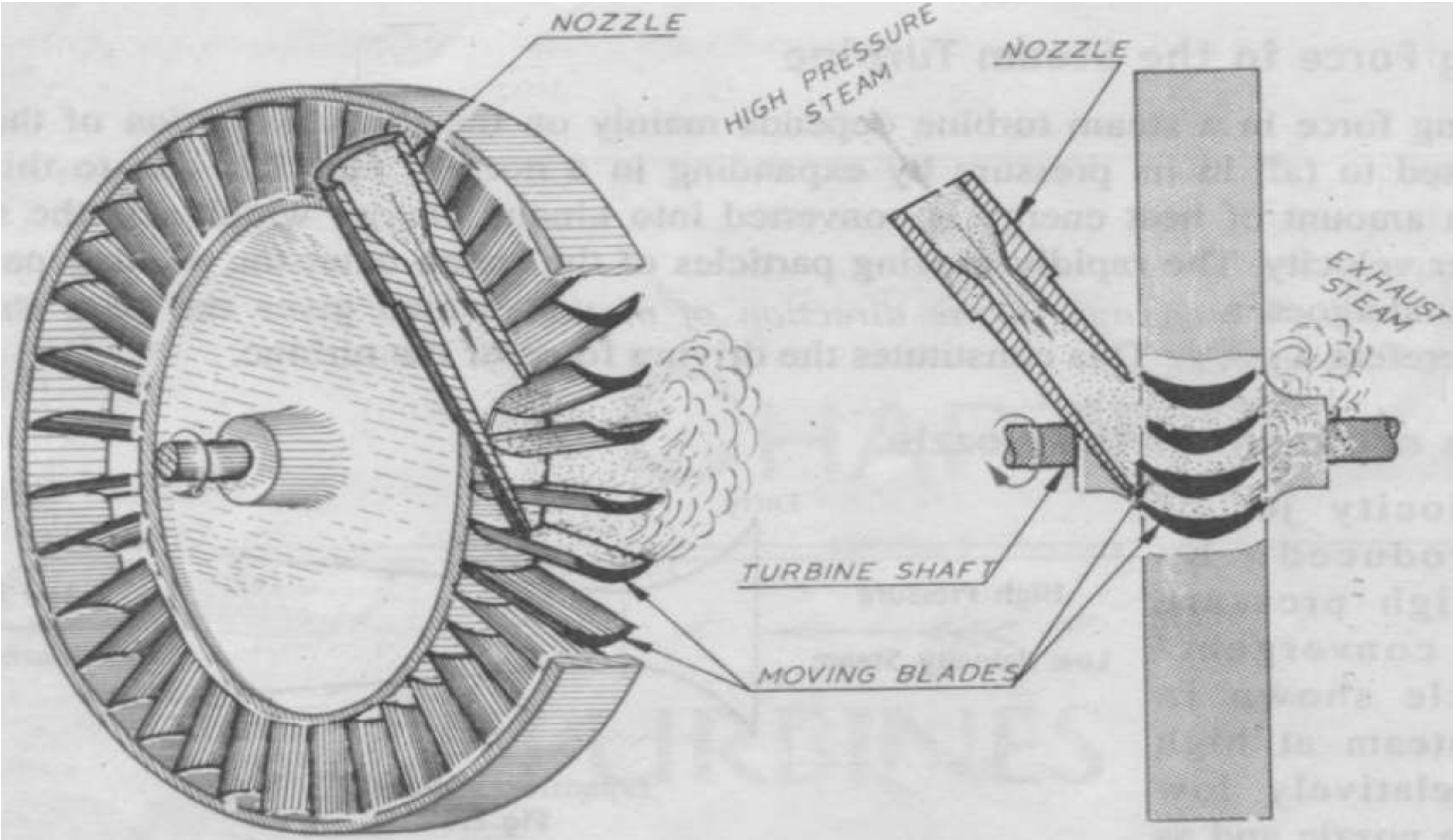
This causes the particles of steam to suffer a change in the direction of motion, which gives rise to a change of momentum and therefore a force, which will be centrifugal in nature.




The particles of steam exert centrifugal pressures all along their path on the curved surface of the blades.

The resultant of all these centrifugal forces acting on the entire curved surface of the blade causes it to move.

When a number of such blades are fitted on the circumference of a revolving wheel, called rotor, they will be moved by the action of the steam, and they in turn sets the rotor in continuous rotation.




The rotation of the rotor makes all the blades fitted on the rim to get exposed to the action of the steam jet in succession.

Although there is no direct impulsive action on the moving blade that is causing the turbine rotor to rotate, but the impelling action of the jet of steam on the blades drives the rotor to rotate in the same direction of the propelling force, this type of turbine is called **impulse turbine.**

The examples of impulse turbines are De Laval Turbine, Curtis turbine, Zoelly turbine, Rateau turbine.

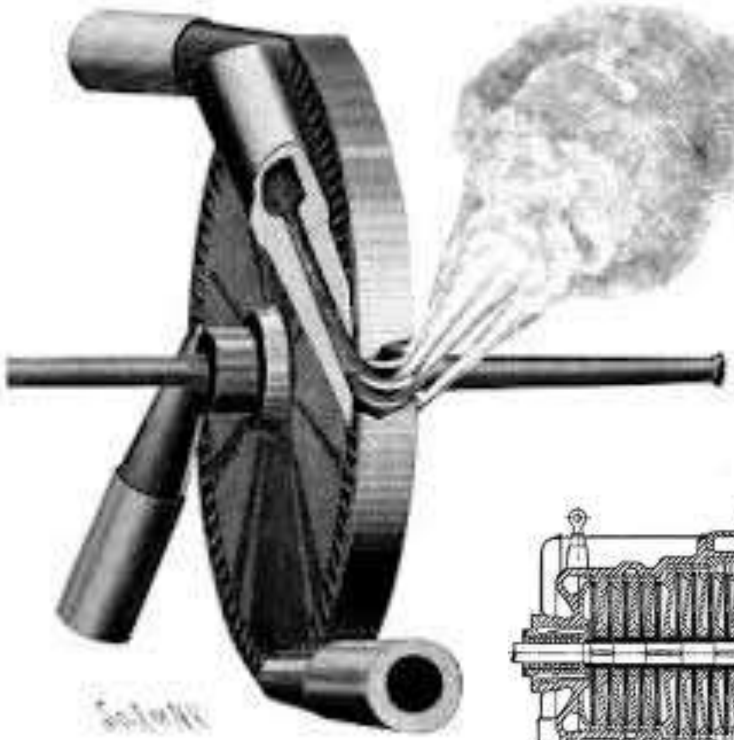
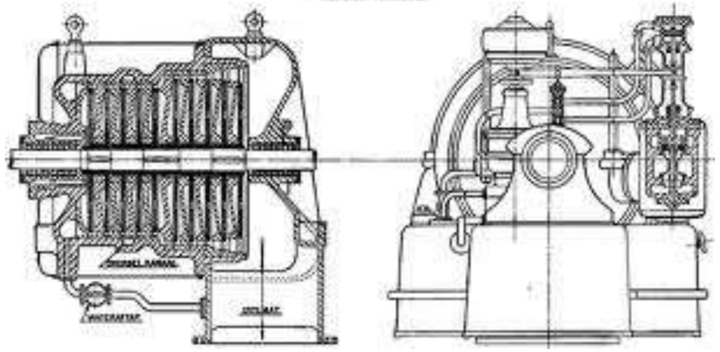
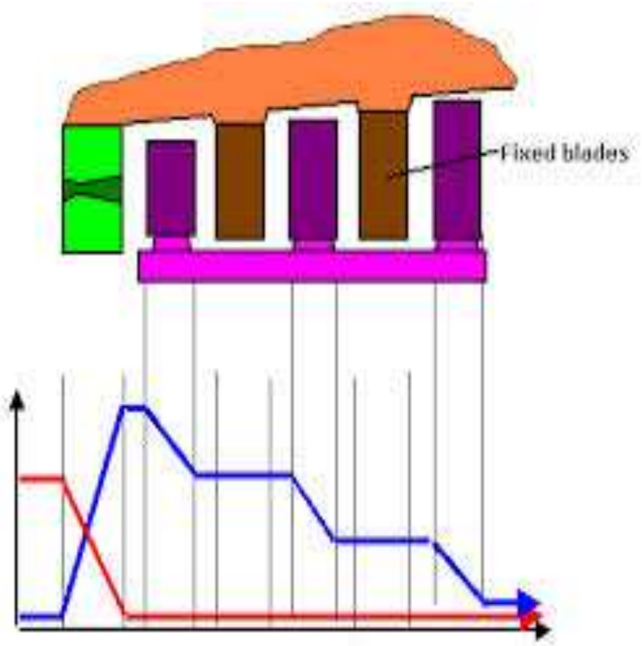
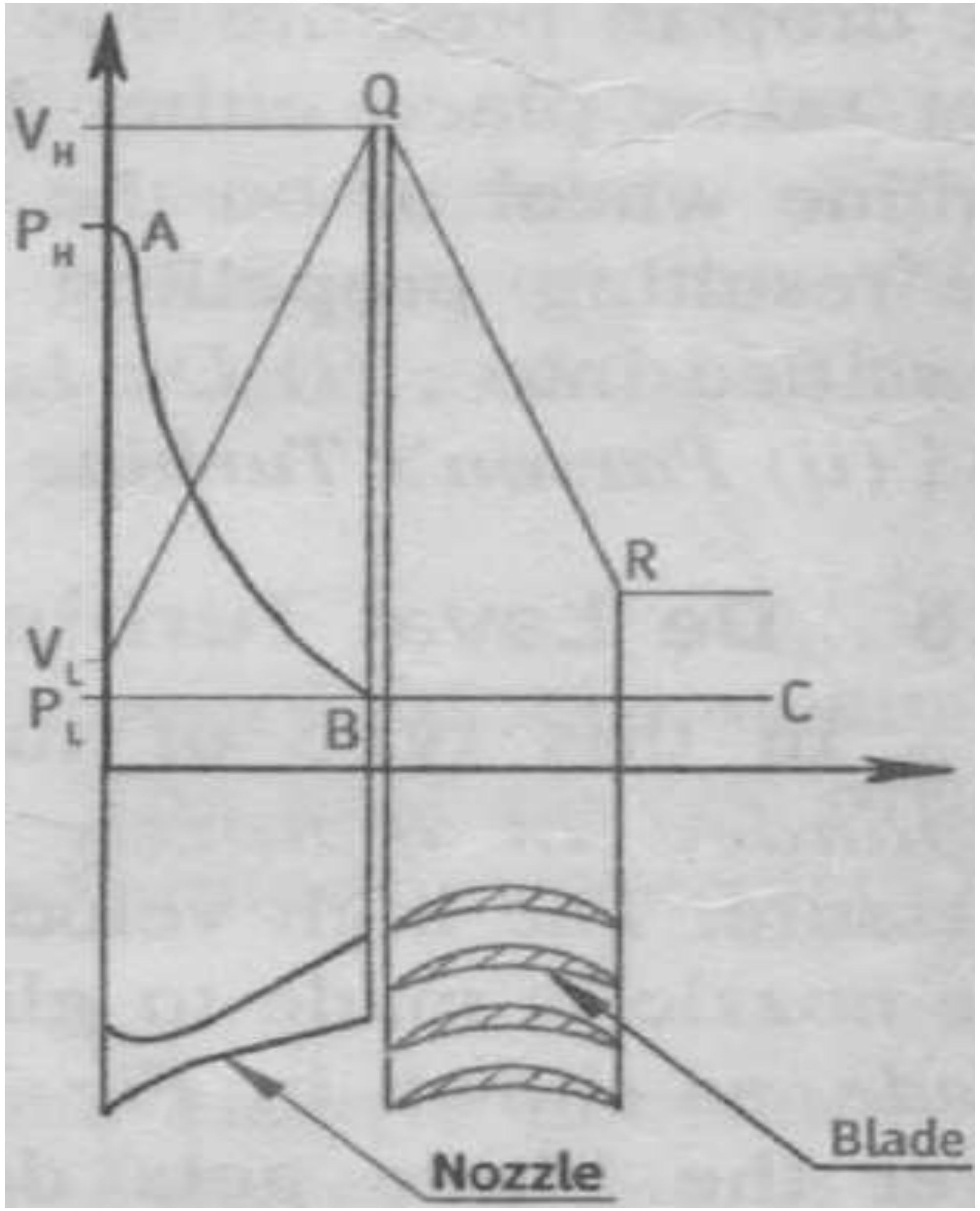


FIG. 55.
ZOELLY-TURBINE.



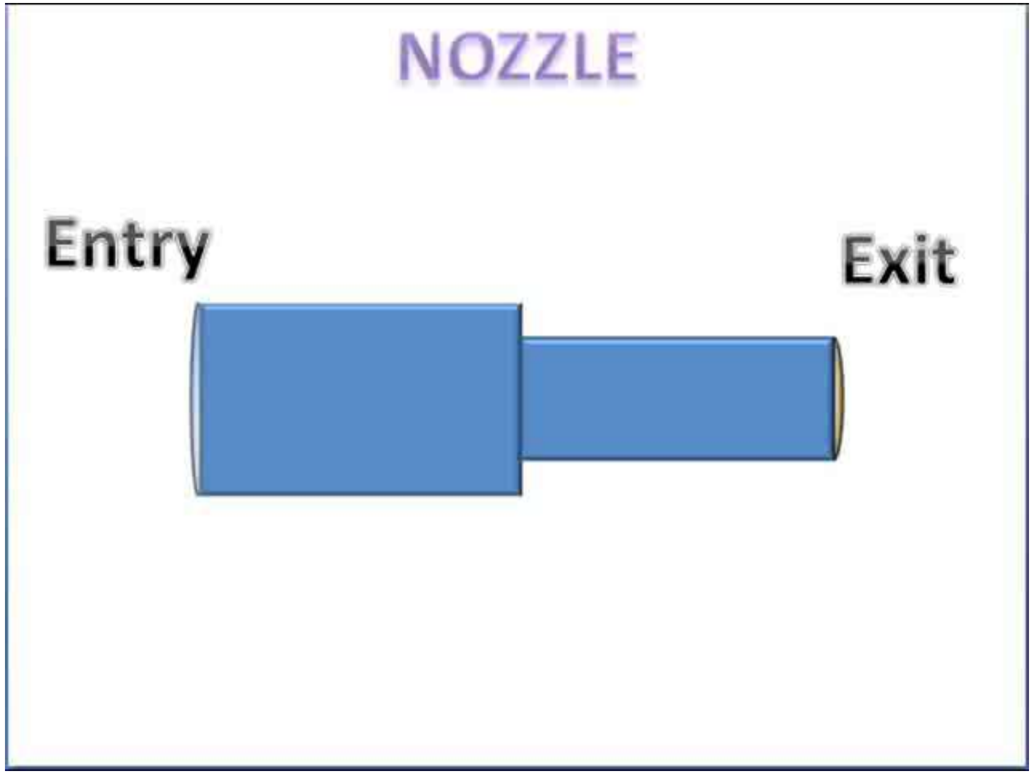


# Pressure Velocity Changes in Impulse Turbine

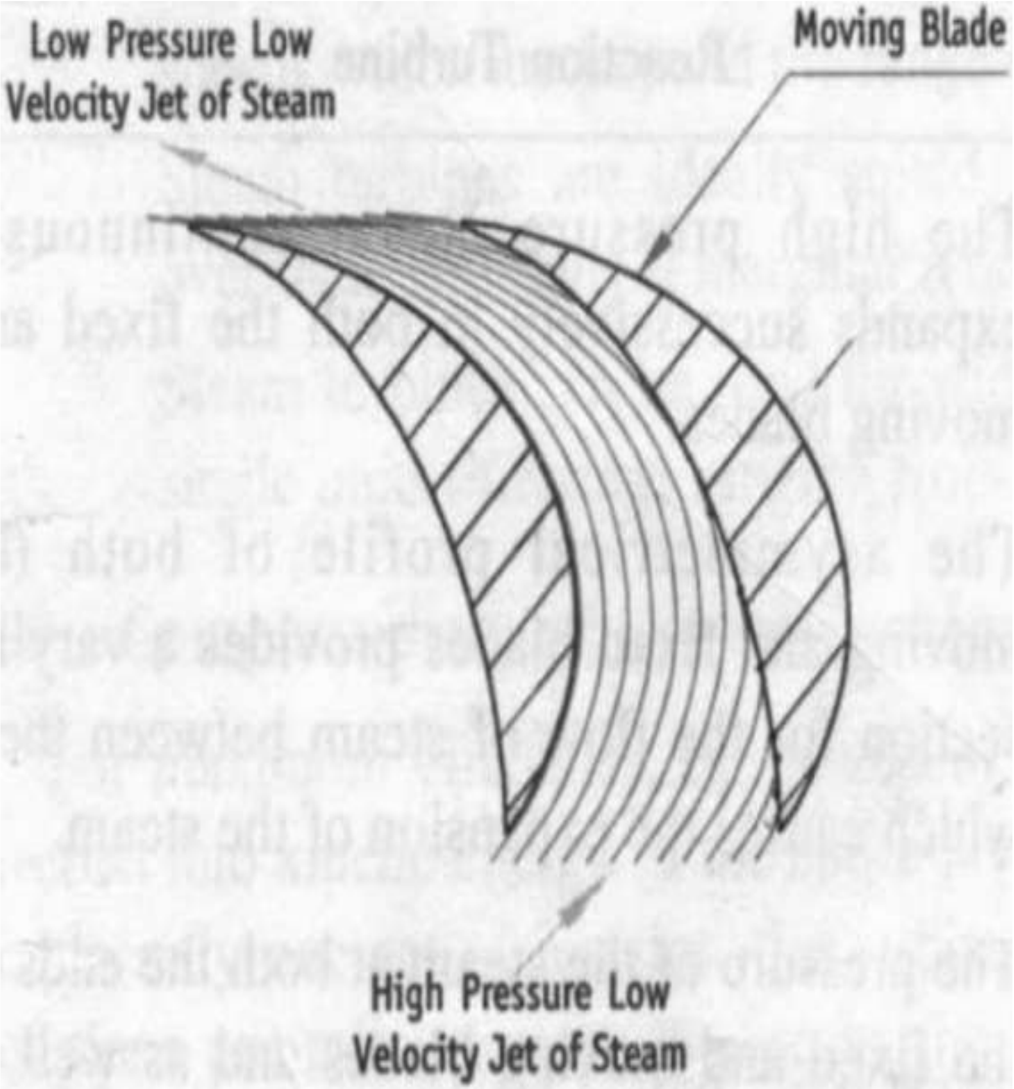



- The lower portion shows the nozzle and the blade, and the top portion shows the variation of pressure and velocity of the steam as it flows through the nozzle and over the blades.
- Since the expansion of the steam takes place in the nozzle, the pressure drop is represented by the curve AB.
- As there is no change in the pressure of the steam that is passing over the blade, this flow is represented by the horizontal line BC.
- Since the velocity of the steam in the nozzle increases due to the expansion of the steam, the increase in the velocity of the steam is represented by the curve VLQ.
- As the blades absorb the kinetic energy of the steam as it flows over it, the velocity decreases. This is represented by the curve QR.

# Impulse Steam turbine animation

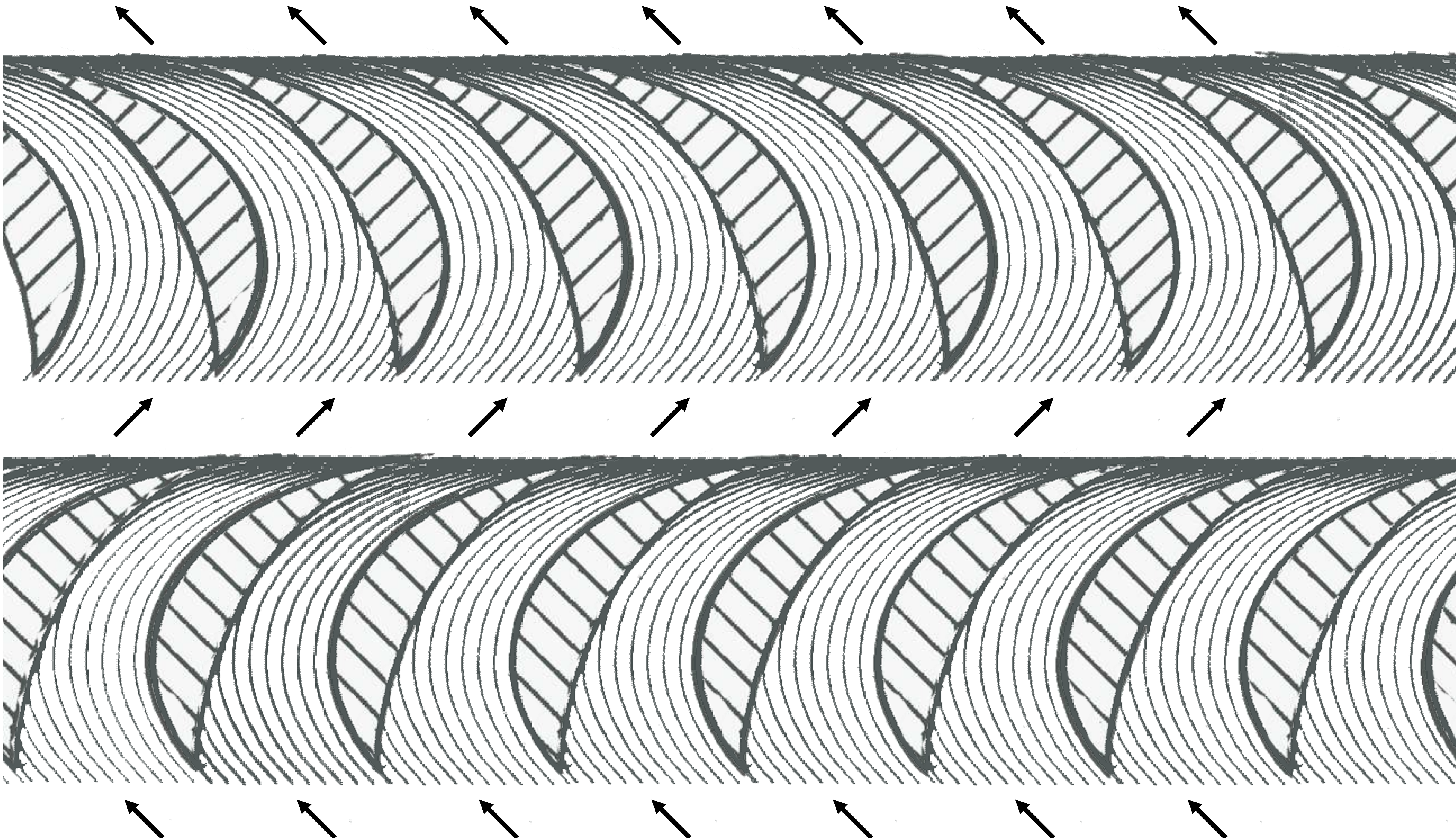


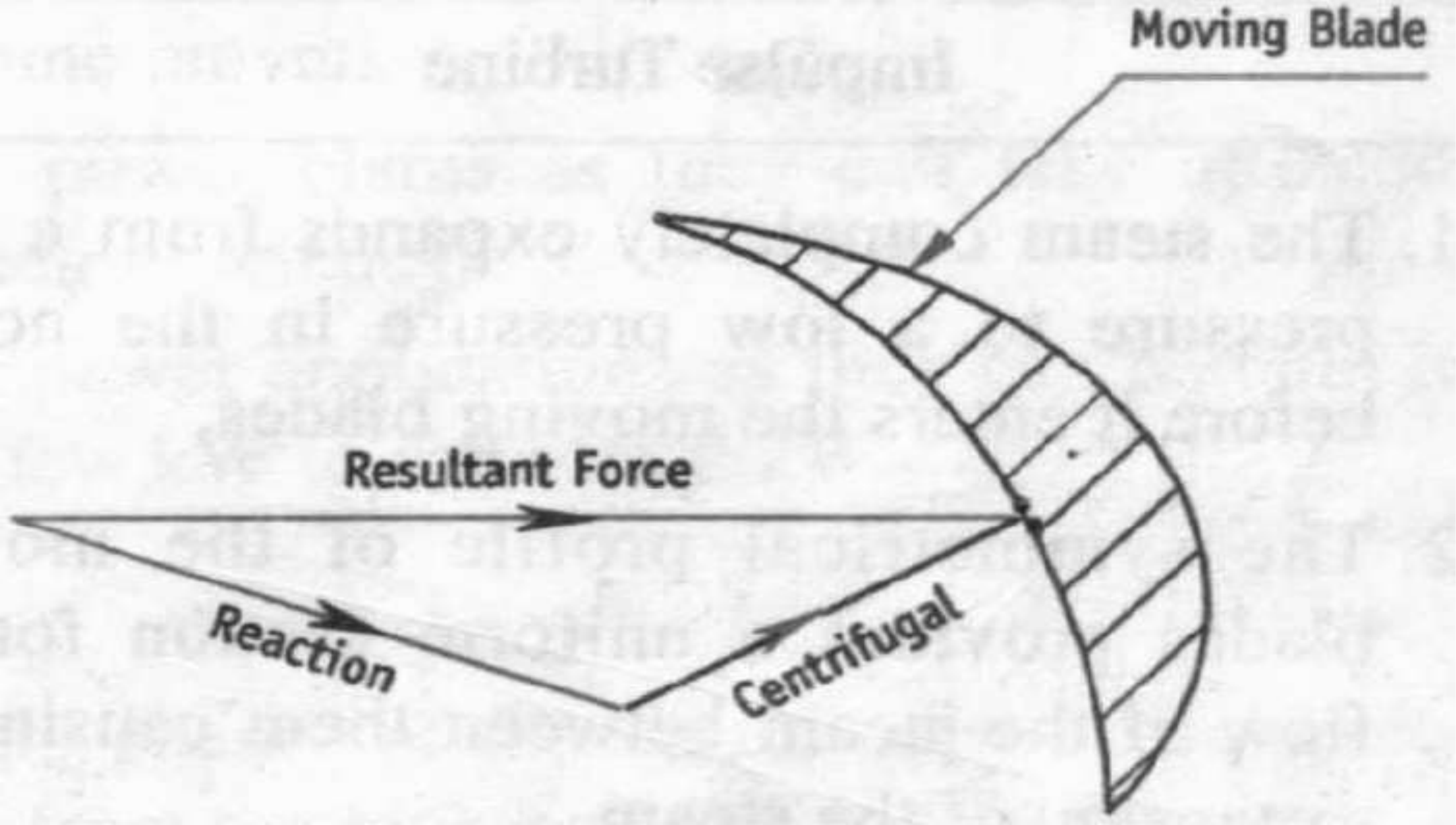
# Reaction Steam Turbine




**In this type of turbine the <u>high pressure steam does not initially expand in the nozzle</u> as in the case of impulse turbine, but instead directly passes onto the moving blades, whose shapes are designed in such a way that the <u>steam flowing between the blades will be subjected to the nozzle effect.</u>**

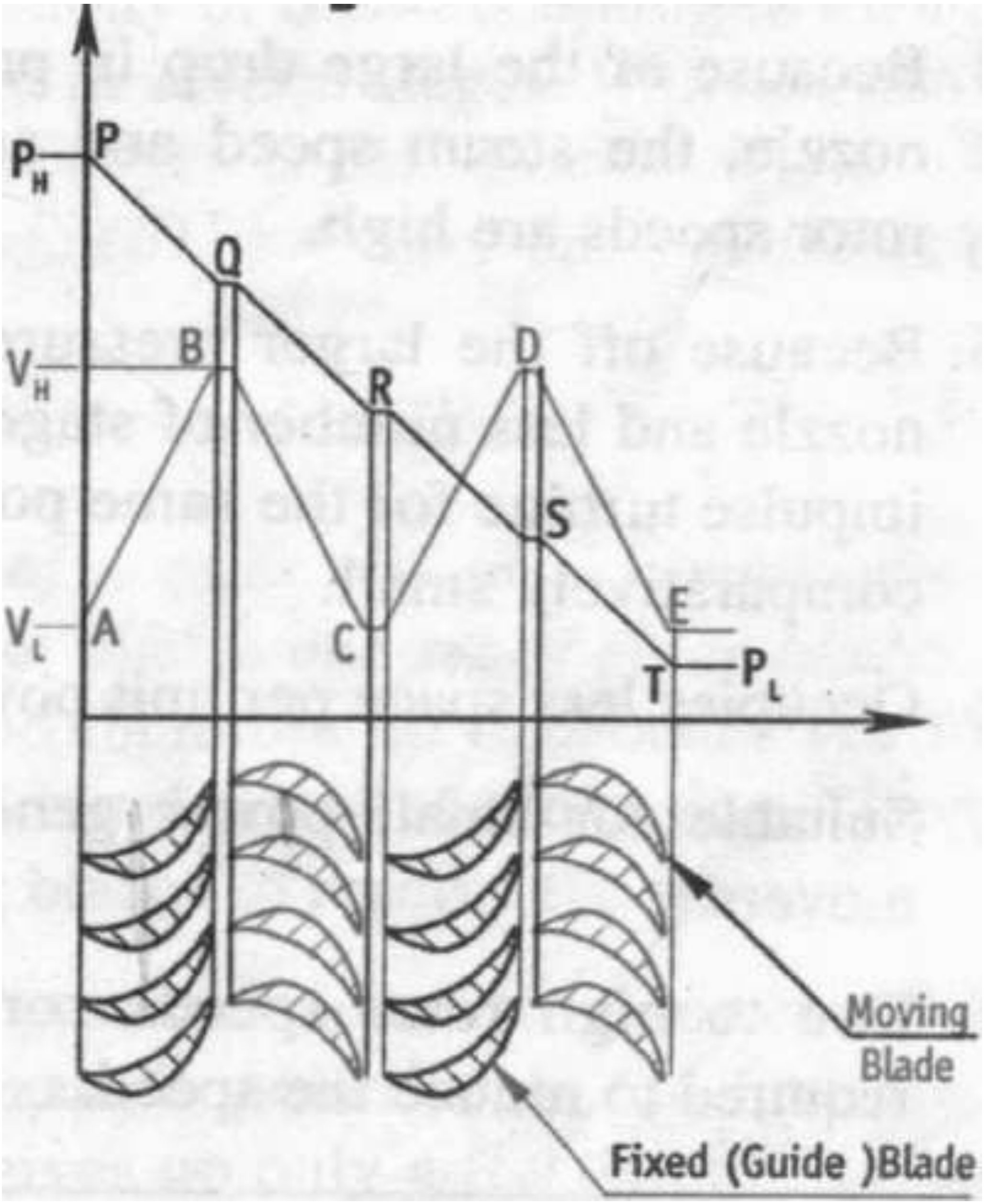
**Hence the pressure of the steam drops continuously as it flows over the blades causing simultaneous increase in the velocity of the steam.**



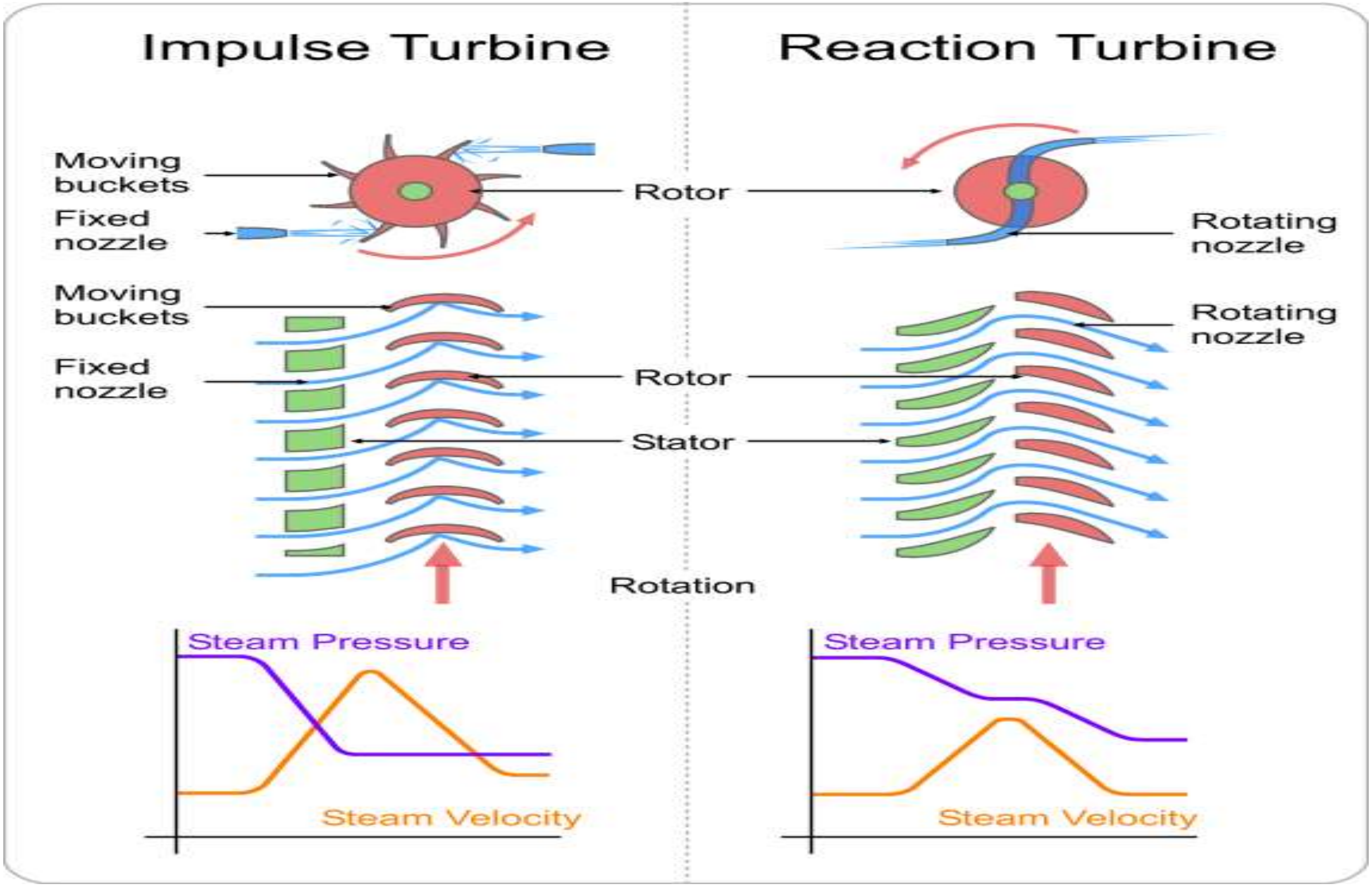



**This reduces the velocity of the steam. Thus the net force acting on the moving blades of a reaction turbine is the vector sum of the centrifugal and the reaction forces. This type of turbine is called reaction turbine.**

# Pressure Velocity Changes in Reaction Turbine




- Both the fixed and moving blades are designed in the shape of the nozzles.
- Therefore the expansion of the steam takes place both in the fixed and moving blades.
- The fixed blade ring between the moving blade rotors enables to deflect and guide the steam to enter from one row of moving blades to the next row.
- The high pressure steam passing in the first row of fixed blades undergoes a small drop in pressure causing the increase in the velocity of the steam.
- It then enters the first row of moving blades where it suffers further drop in pressure and the velocity energy is converted into the mechanical energy of rotation of the rotor.
- Thus the velocity of the steam decreases.
- This continues in the further rows of moving and fixed blades till the pressure of the steam is almost completely reduced.


Impulse Turbine
Reaction Turbine
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Moving buckets
Fixed nozzle
Rotor
Stator
Rotating nozzle
Rotation
Steam Pressure
Steam Velocity
Steam Pressure
Steam Velocity

| | Impulse Turbine | Reaction Turbine |
|---|---|---|
| 1 | Steam completely expands from high pressure to low pressure in the nozzle. | High pressure steam continuously expands in both fixed & moving blades successively. |
| 2 | Symmetrical profile of the moving blades.<br>➔ Causes no expansion of the steam. | Asymmetrical profile of both fixed & moving blades.<br>➔ Causes expansion of the steam. |
| 3 | Steam pressure at the entry & exit of the moving blades remains constant. | Steam pressure at the ends of fixed & moving blades are different. |

| | Impulse Turbine | Reaction Turbine |
|---|---|---|
| 4 | Large pressure drop of steam in the nozzle. → Rotor speeds are high. | Smaller pressure drop over fixed & moving blades. Rotor speeds are low. |
| 5 | Large pressure drop of steam & less no. of stages. → Turbine size is small for the same power output. | Smaller pressure drop of steam & more no. of stages. → Turbine size is large for the same power output. |
| 6 | Occupies less space per unit power. | Occupies more space per unit power. |
| 7 | Suitable for small power generation. | Suitable for medium & high power generation. |

# Q & A

- If you have any queries, post them in the chat box of MS Teams.

# Thank You