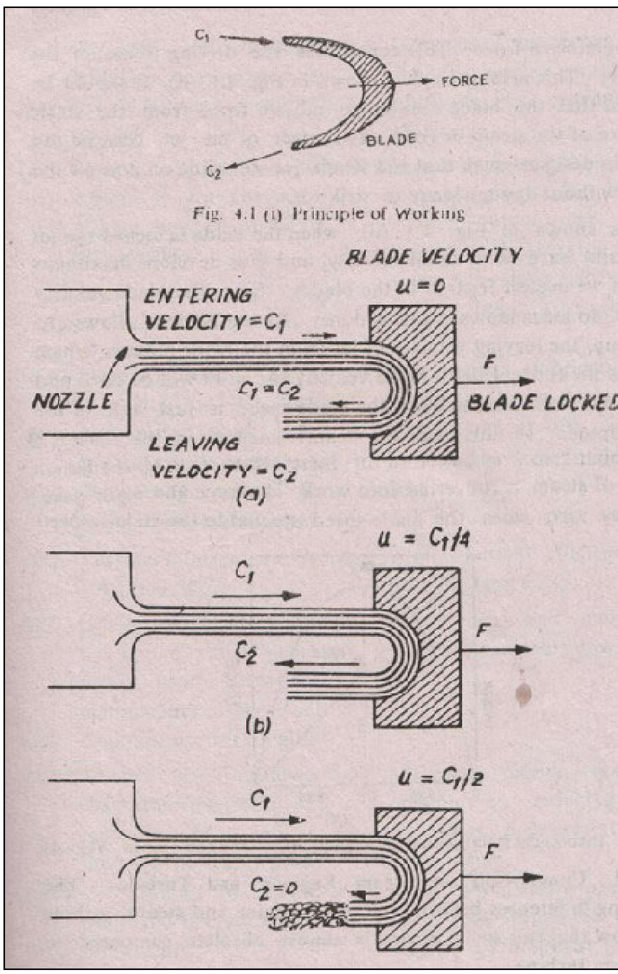
Fundamentals of steam turbine systems

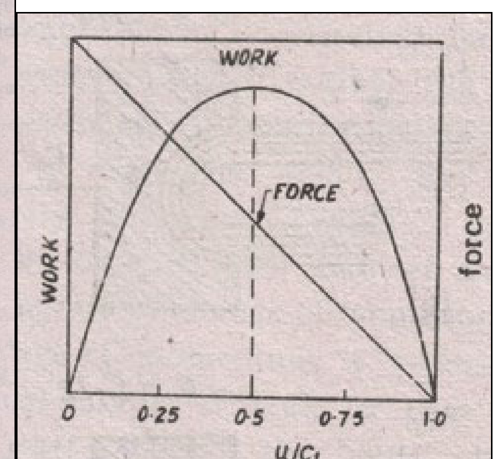
Principles of operation

- The motive power in a steam turbine is obtained by the rate of change in momentum of a high velocity jet of steam impinging on a curved blade which is free to rotate.

- The steam from the boiler is expanded in a nozzle, resulting in the emission of a high velocity jet. This jet of steam impinges on the moving vanes or blades, mounted on a shaft. Here it undergoes a change of direction of motion which gives rise to a change in momentum and therefore a force.

- Principle of operation is shown below:





Theoretical Relationship between Work, Force and Blade Velocity

- The relationship between work, force and blade velocity can be expressed in the other graph.

- Steam turbines are mostly 'axial flow' types; the steam flows over the blades in a direction parallel to the axis of the wheel. 'Radial flow' types are rarely used.

Classification of steam turbines

- On the basis of operation, steam turbines can be classified as: (i) Impulse turbine and (ii) Impulse-reaction turbine.

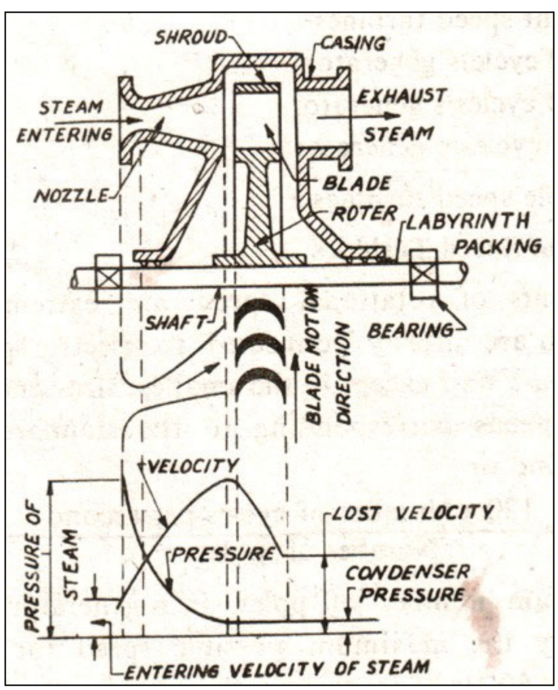
  Impulse turbine
  In impulse turbine, the drop in pressure of steam takes place only in nozzles and not in moving blades. This is obtained by making the blade passage of constant cross-sectional area.

  Impulse-Reaction turbine
- In this type, the drop in pressure takes place in fixed nozzles as well as moving blades.
- The pressure drop suffered by steam while passing through the moving blades causes a further generation of kinetic energy within these blades, giving rise to reaction and add to the propelling force, which is applied through the rotor to the turbine shaft.
- The blade passage cross-sectional area is varied (converging type).

The simple Impulse turbine

- It primarily consists of: a nozzle or a set of nozzles, a rotor mounted on a shaft, one set of moving blades attached to the rotor and a casing.

- A simple impulse turbine can be diagrammatically represented below. The uppermost portion of the diagram shows a longitudinal section through the upper half of the turbine, the middle portion shows the actual shape of the nozzle and blading, and the bottom portion shows the variation of absolute velocity and absolute pressure during the flow of steam through passage of nozzles and blades. Example: de-Laval turbine

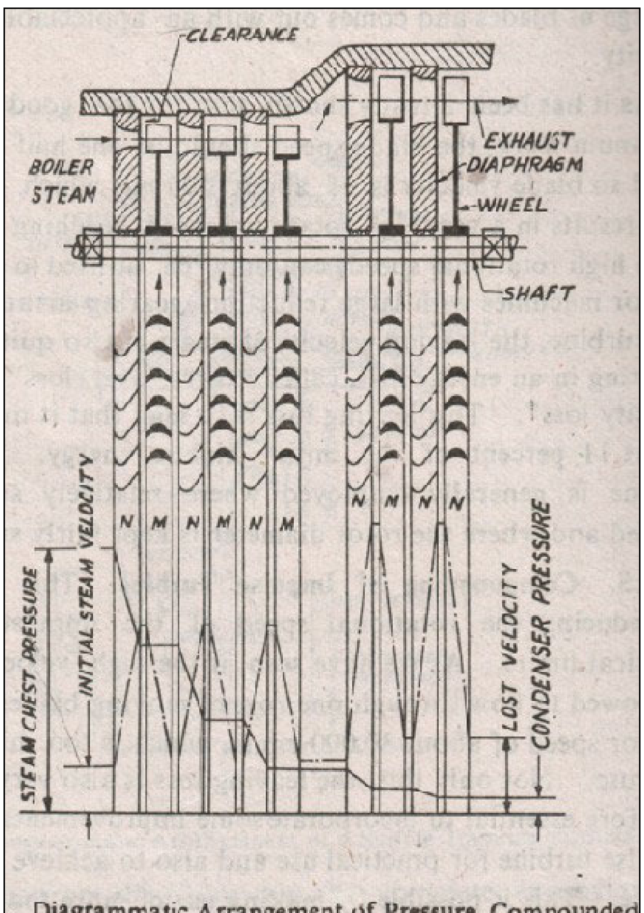


Compounding of impulse turbine

- This is done to reduce the rotational speed of the impulse turbine to practical limits. (A rotor speed of 30,000 rpm is possible, which is pretty high for practical uses.)
- 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.
- Three main types of compounded impulse turbines are:
  a) Pressure compounded, b) velocity compounded and c) pressure and velocity compounded impulse turbines.

Pressure compounded impulse turbine

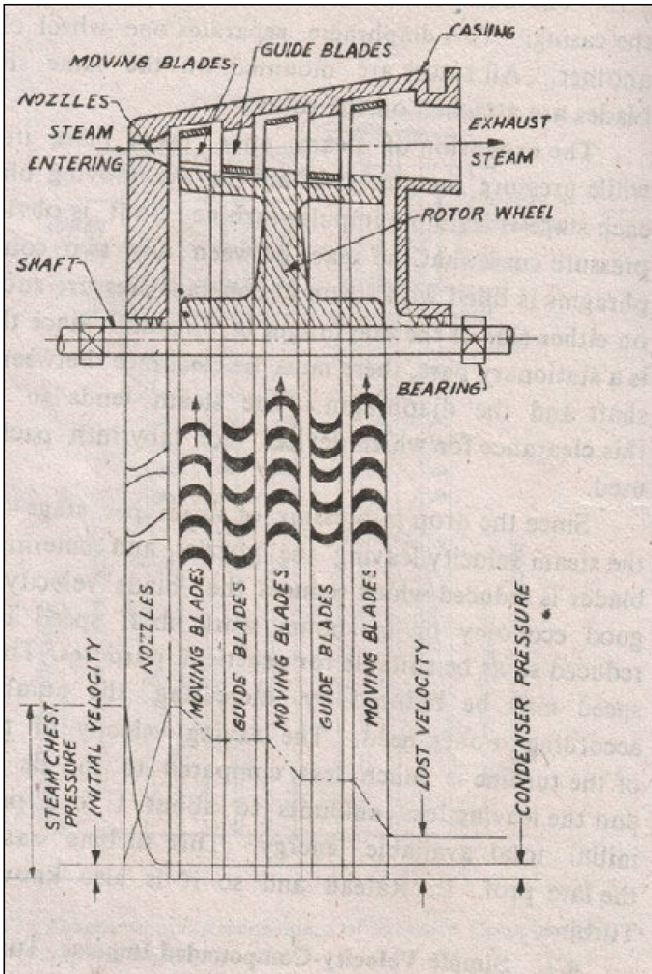
- This involves splitting up of the whole pressure drop from the steam chest pressure to the condenser pressure into a series of smaller pressure drops across several stages of impulse turbine.
- The nozzles are fitted into a diaphragm locked in the casing. This diaphragm separates one wheel chamber from another. All rotors are mounted on the same shaft and the blades are attached on the rotor.
- The pressure and velocity variation are shown in the next diagram.



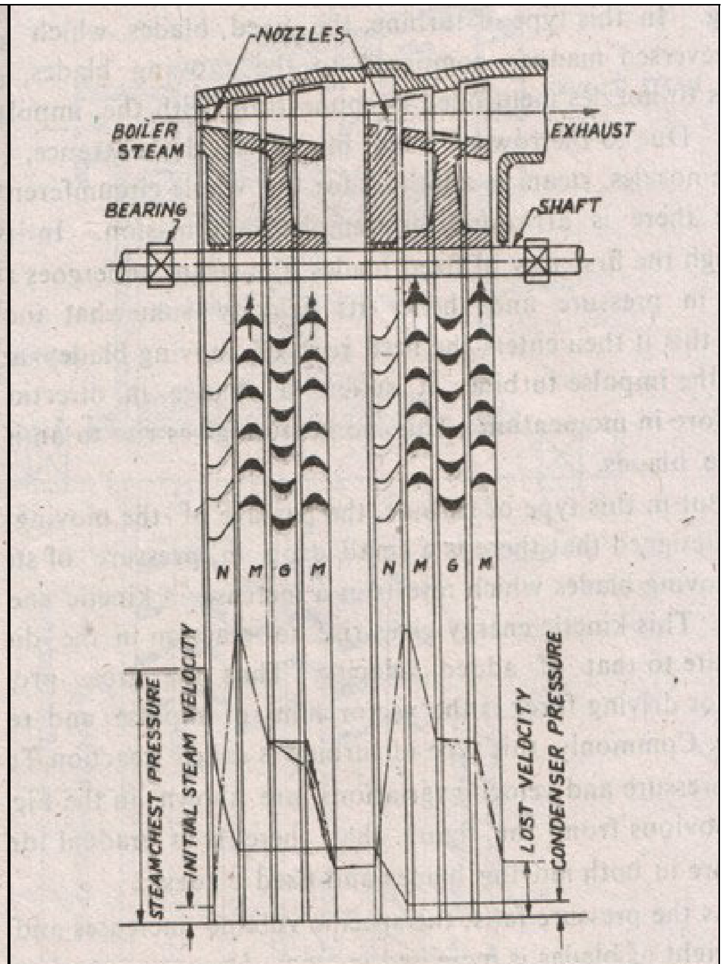
. Diagrammatic Arrangement of Pressure Compounded Impulse Turbine.

Velocity compounded impulse turbine

- Velocity drop is arranged in many small drops through many moving rows of blades instead of a single row of moving blades.
- It consists of a nozzle or a set of nozzles and rows of moving blades attached to the rotor or the wheel and rows of fixed blades attached to the casing.



Diagrammatic arrangement of Velocity Compounded Impulse Turbine.



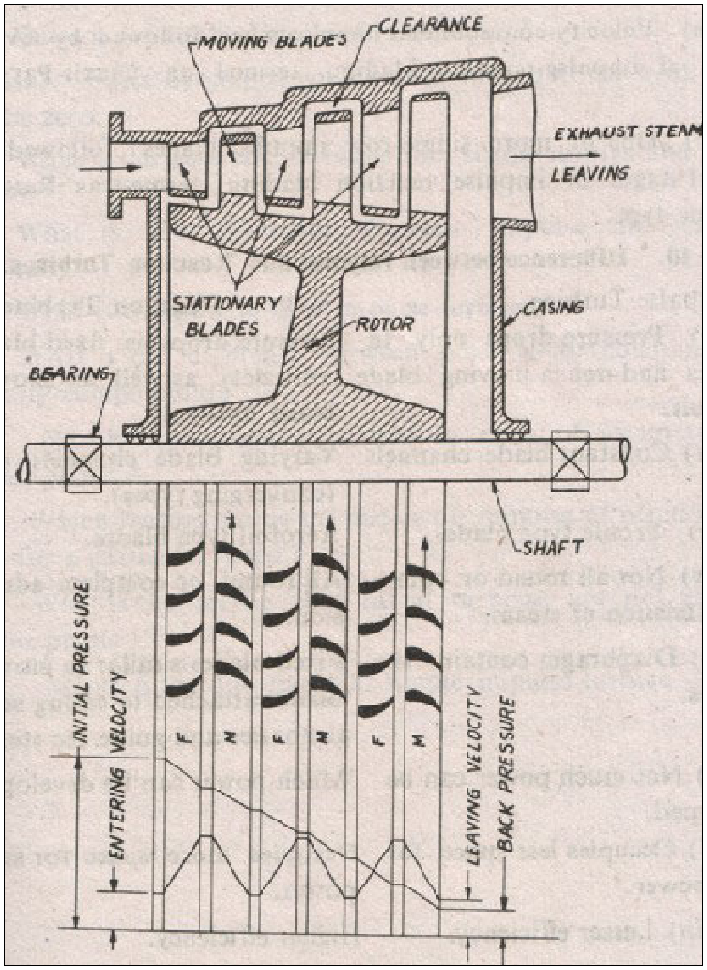
Diagrammatic Arrangement of Pressure-Velocity Compounded Impulse Turbine.

Pressure-velocity compounded impulse turbine

- This is a combination of pressure-velocity compounding.

Impulse-Reaction turbine

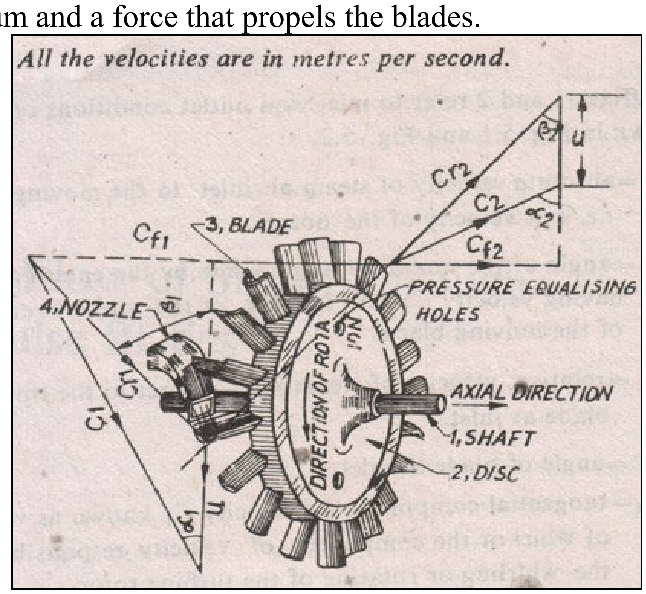
- This utilizes the principle of impulse and reaction. It is shown diagrammatically below:
- There are a number of rows of moving blades attached to the rotor and an equal number of fixed blades attached to the casing. The fixed blades are set in a reversed manner compared to the moving blades, and act as nozzles. Due to the row of fixed blades at the entrance, instead of nozzles, steam is admitted for the whole circumference and hence there is an all-round or complete admission.



Differences between Impulse and Reaction turbines

Velocity diagram for Impulse turbines

The main parts of an impulse turbine are nozzles and blades. Nozzles produce a jet of steam of high velocity and the blades change the direction of the jet, thus producing a change in momentum and a force that propels the blades.



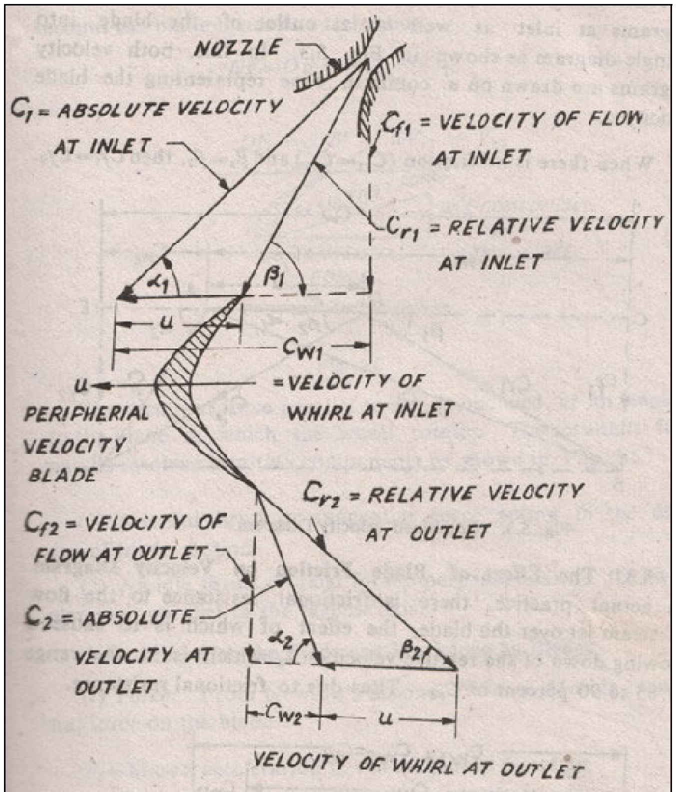
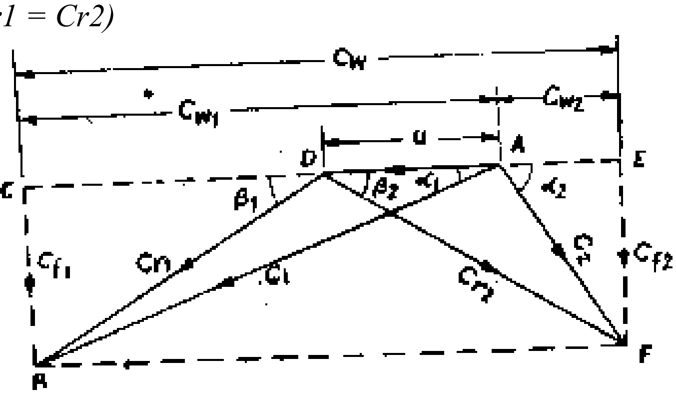


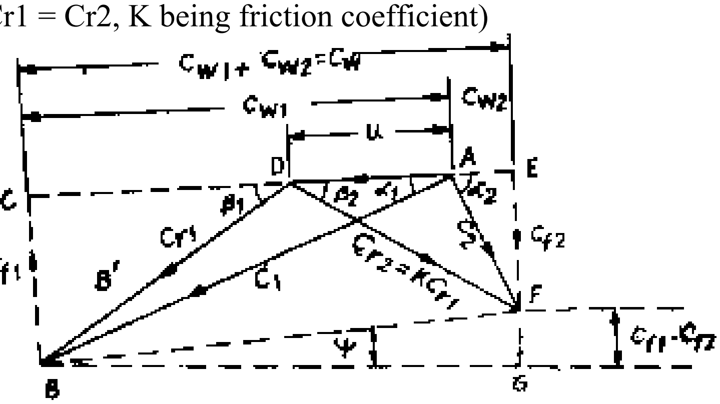
Fig. 5.2. Velocity Diagram for Impulse Turbine

Combination of vector diagrams

Without friction (Cr1 = Cr2)



With friction (K.Cr1 = Cr2, K being friction coefficient)



Velocity diagram for Impulse-Reaction turbines

Degree of reaction

The degree of reaction is defined as the ratio of isentropic heat drop in the moving blades to the sum of the isentropic heat drops in the fixed and the moving blades, i.e. in a stage. (Or, the fraction of the total decrease in enthalpy that occurs across the rotor)