HYDRAULICS & HYDRAULIC MACHINES

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Classification of Turbines

- **According to the Type of Energy at Inlet**
  - Impulse
  - Reaction
- **Direction Of Flow Through Runner**
  - Tangential flow turbine
  - Radial flow turbine
  - Axial flow turbine
  - Mixed flow turbine.
- **According To the Head at the Inlet of Turbine**
  - High head turbine
  - Medium head turbine
  - Low head turbine
- **According to the specific speed of the turbine**
  - High specific speed turbine
  - Medium specific speed turbine
  - Low specific speed turbine

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·**<u>IMPULSE TURBINE</u>**:- If at inlet of turbine, the energy available only kinectic energy, the turbine is known as impulse turbine.

Ex. Pelton Wheel Turbine

·**<u>REACTION TURBINE</u>**:- If at inlet of turbine, the water possesses kinetic energy, the turbine iss known as reaction turbine.

Ex. Francis Turbine, Kaplan Turbine

·**TANGENTIAL FLOW TURBINE**:- If the water flows along the tangent of runner, the turbine is known as tangential flow turbine .

·**AXIAL FLOW TURBINE**:- If the water flow through the runner along the direction parallel to the axis of rotation of the runner, the turbine is called axial flow turbine.

·**RADIAL FLOW TURBINNE**:- If the water flow in radial direction through runner, the turbine is called radial flow turbine.

· **INWARD RADIAL FLOW TURBINE**:- If the water fl
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from outward to inward radial flow turbine.

· **OUTWARD RADIAL FLOW TURBINE**:- If the water flows from inward to outward radial flow turbine.

· **MIXED FLOW TURBINE**:- If the water flows the runner in the radial direction but leaves in the direction parallel to the axis of rotation of the runner, the turbine is called mixed floe turbine.

Tangential Flow Turbine - Pelton Wheel
Radial Flow Turbine - Francis Turbine
Axial Flow Turbine - Kaplan Turbine
Mixed Flow Turbine - Modern Francis Turbine

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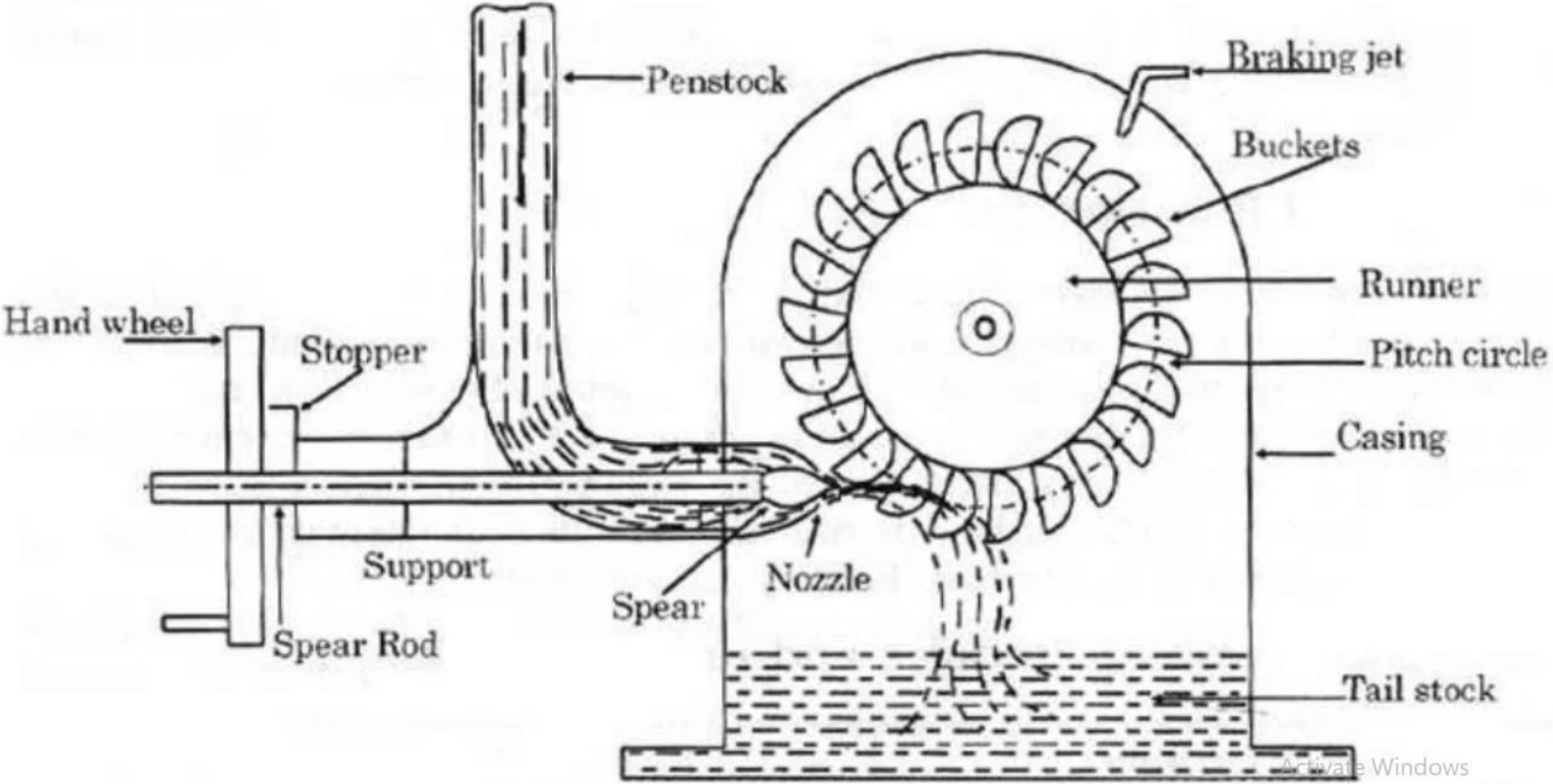
3. According to Head at Inlet of turbine
   a) High Head Turbine - Pelton Wheel
   b) Medium Head Turbine - Fancis Turbine
   c) Low Head Turbine - Kaplan Turbine
4. According to Specific Speed of Turbine
   a) Low Specific Speed Turbine - Pelton Wheel
   b) Medium Specific Speed Turbine - Fancis Turbine
   c) High Specific Speed Turbine - Kaplan Turbine



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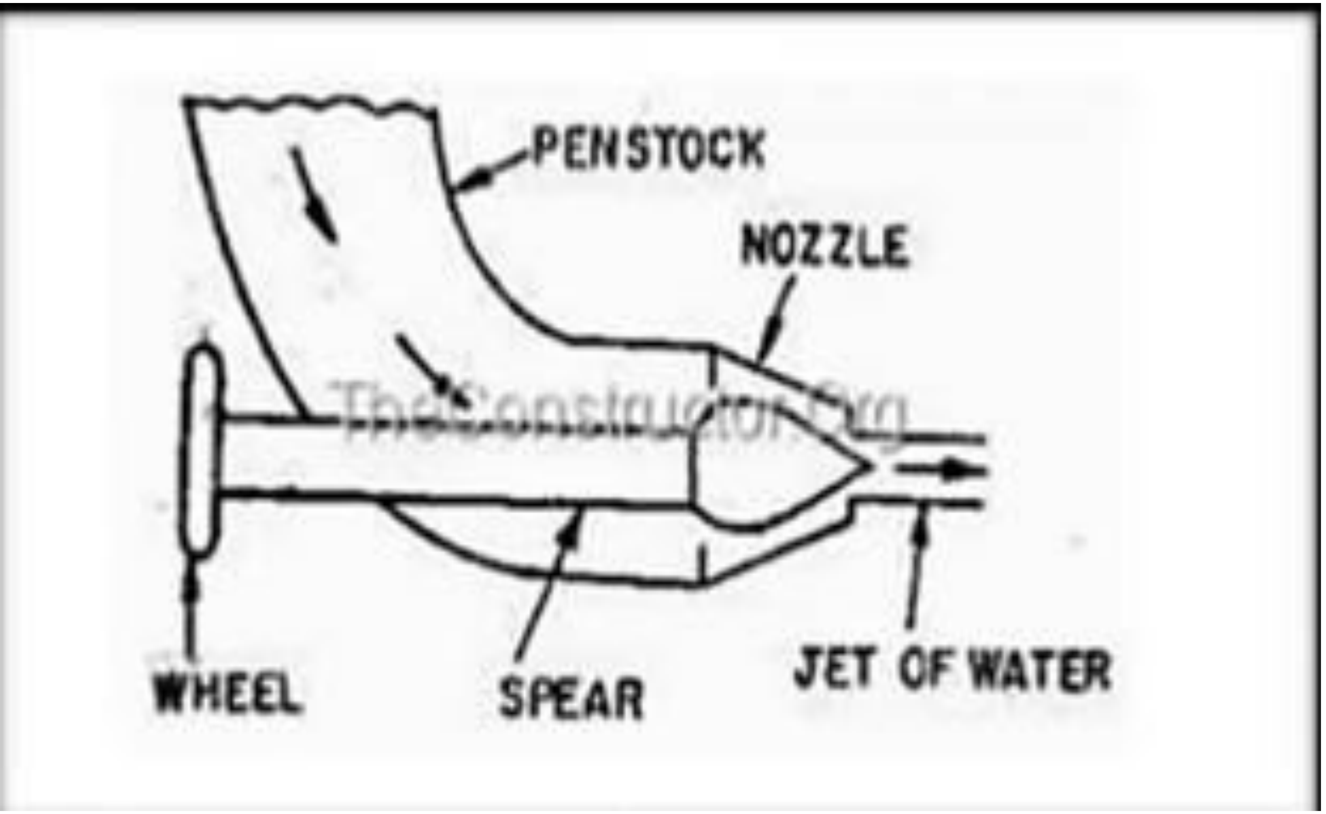
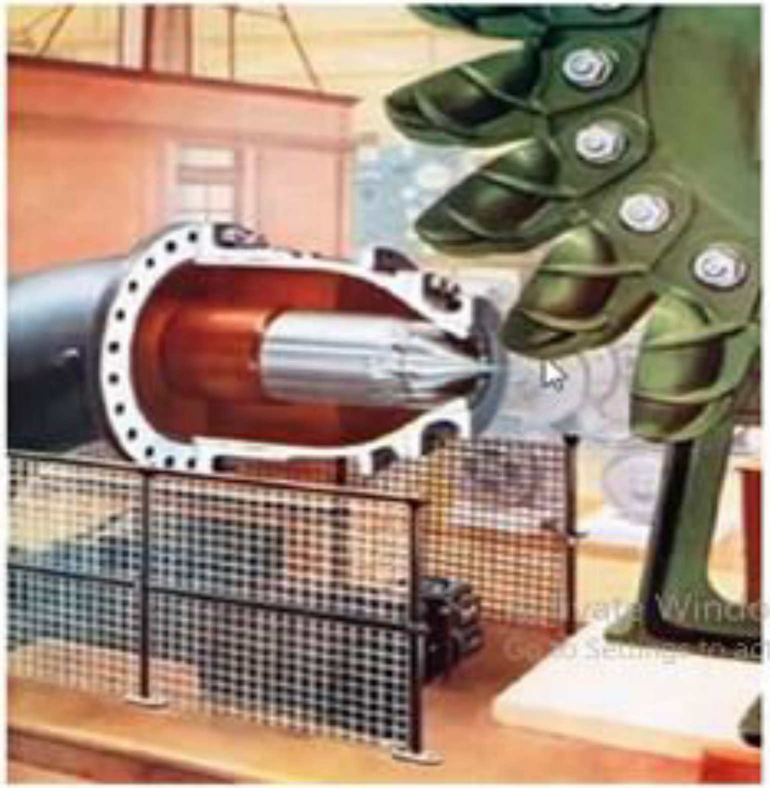
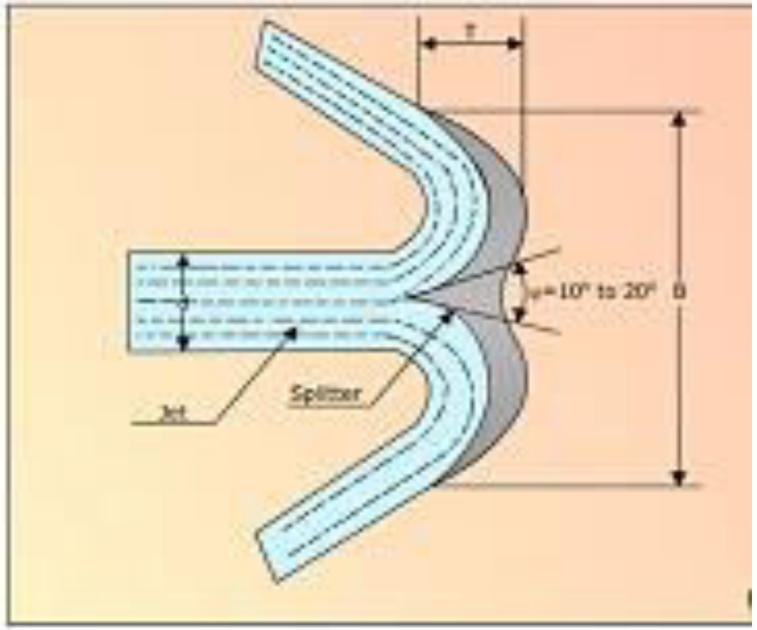
PELTON WHEEL

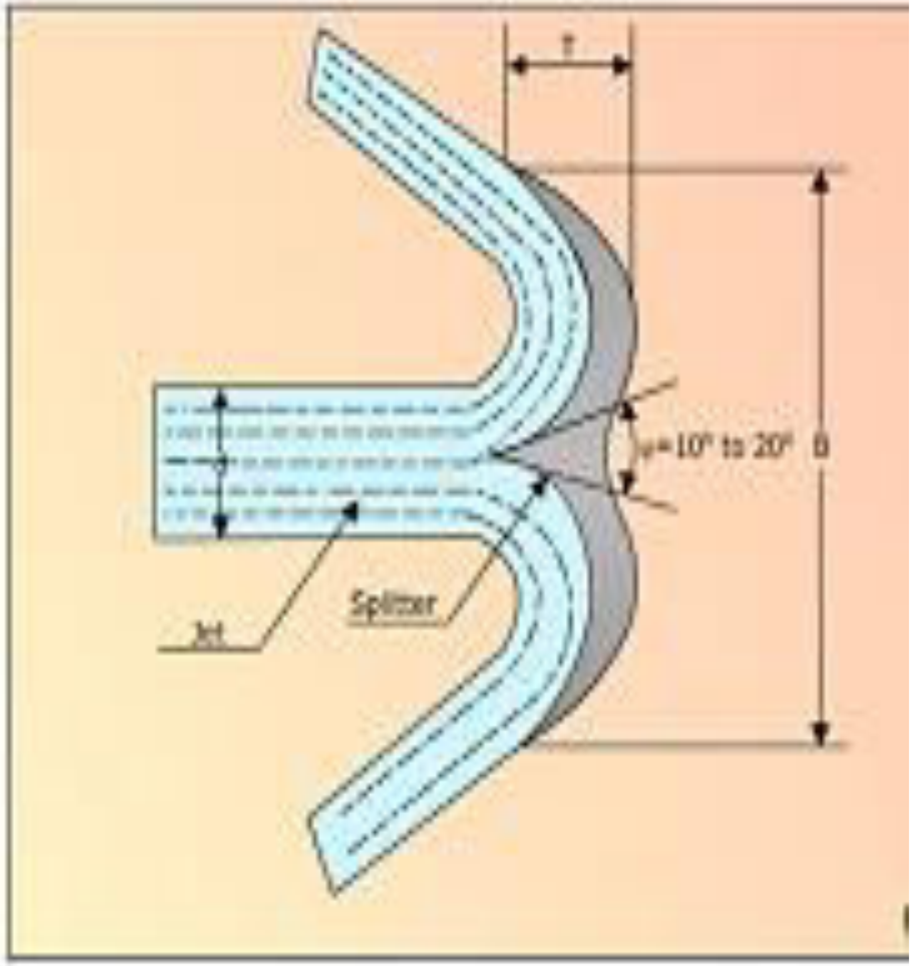
1) Nozzle and flow regulating arrangement (spear) :

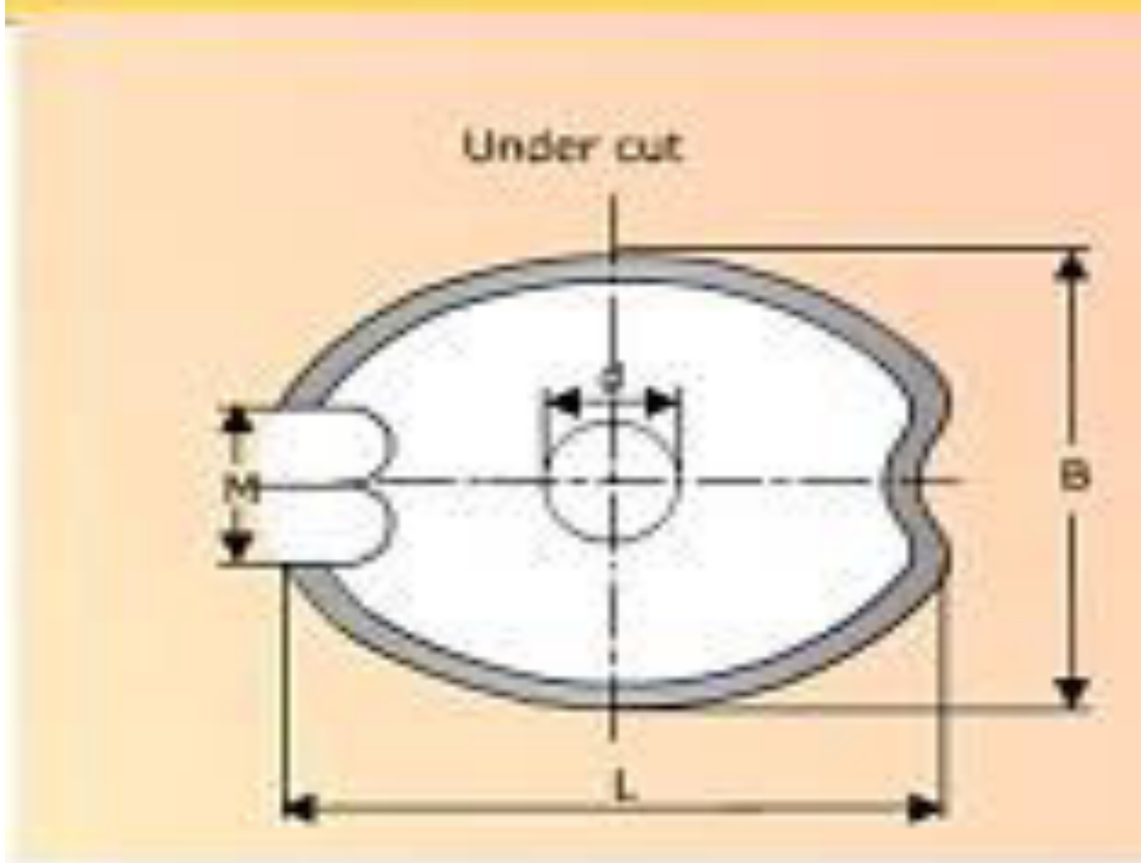




2) Runner and buckets :







The commonly adopted dimensions of bucket are:

d = diameter of jet

L = Length of height of bowl inside the rim = 2 d to 3 d

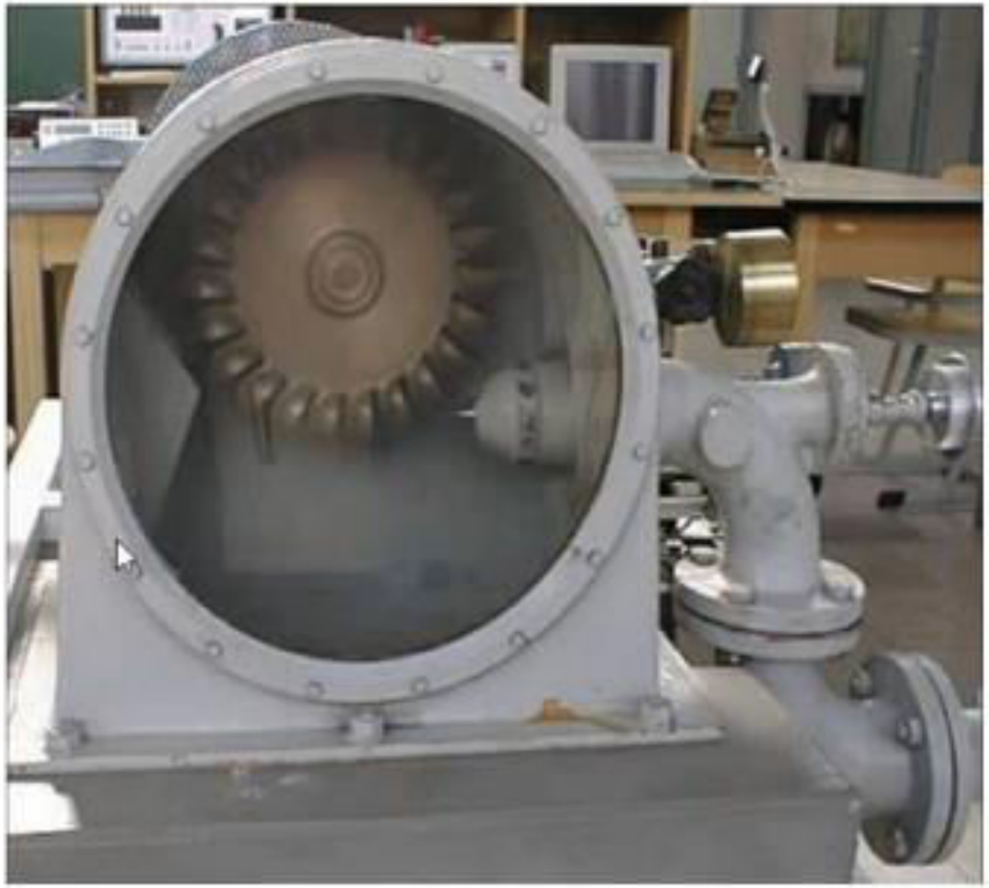
B = Width of bucket between the rims of bowl = 3d to 4d

T = Depth of bowl = 0.27 B to 0.32 B

M = Notch width = 1.1 d to 1.2 d

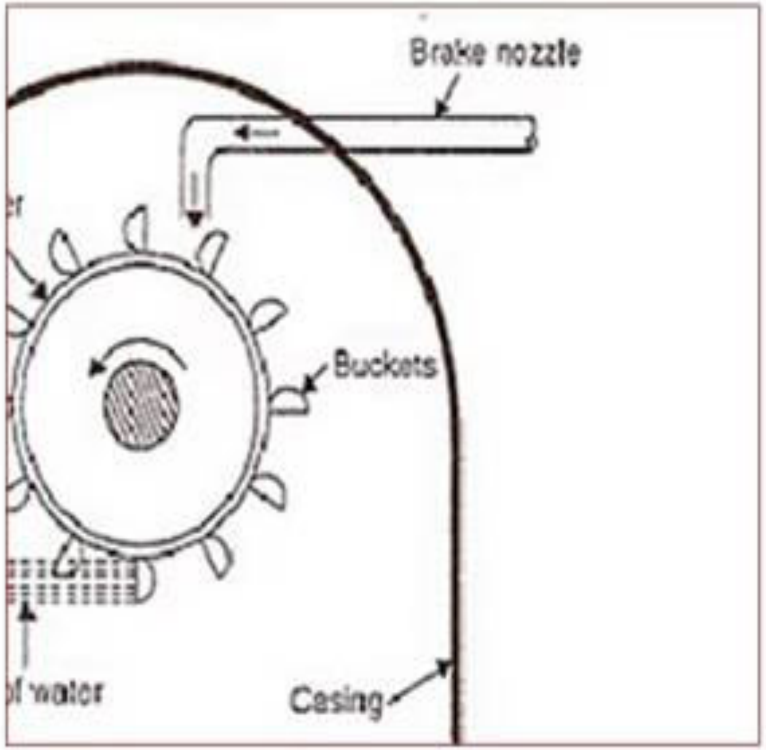
Splitter angle, = 10° to 20°

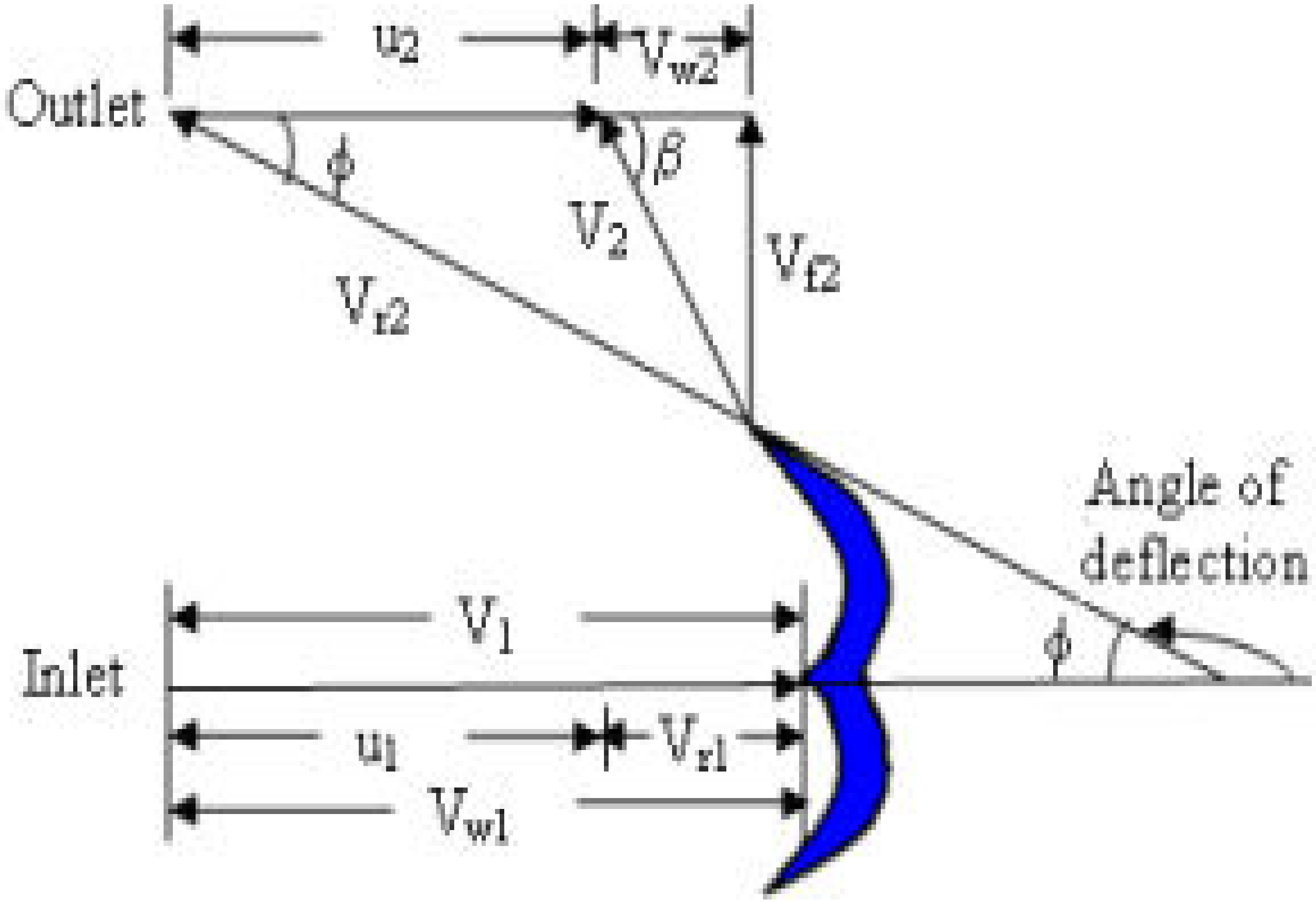
3) Casing :



- The function of casing is to prevent the splashing of the water and to discharge water to tail race.

4) Breaking Jet :





u2
Vw2
Outlet
ϕ
β
V2
Vf2
Vr2
Angle of
deflection
V1
ϕ
Inlet
u1
Vr1
Vw1

The velocity Δ at inlet will be a straight line,

$$V_{w1} = V_1$$

$$V_{r1} = V_1 - u_1 = V_1 - u$$

The velocity Δ at outlet,

$$V_{r1} = V_{r2}, \qquad V_{w2} = V_{r2} \cos\phi - u_2$$

The force exerted by jet of water in the direction of motion,

$$F_x = \rho a V_1 [V_{w1} + V_{w2}]$$

Mass of water striking $= \rho a V_1$

Workdone by the jet on the runner / sec $= F_x \times u = \rho a V_1 [V_{w1} + V_{w2}] \times u, \quad Nm/s$

Power given to the runner by jet $= \dfrac{\rho a V_1 [V_{w1} + V_{w2}] \times u}{1000}, KW$

$$\text{Workdone/s per unit weight of water} = \frac{\rho a V_1 [V_{w1} + V_{w2}] \times u}{\textit{Weight of water striking/s}}$$

$$= \frac{\rho a V_1 [V_{w1} + V_{w2}] \times u}{\rho a V_1 \times g}$$

$$= \frac{[V_{w1} + V_{w2}] \times u}{g}$$

$$\text{Hydraulic efficiency}, \eta_h = \frac{\textit{Workdone/s}}{\textit{K.E of jet/s}}$$

$$\textit{K.E of jet/s} = \frac{1}{2} m V^2$$

$$= \frac{1}{2} \rho a V_1 (V_1^2)$$

$$= \frac{1}{2} \rho a V_1^3$$

$$\text{Hydraulic efficiency, } \eta_h = \frac{\rho a V_1 [V_{w1} + V_{w2}] x\, u}{\frac{1}{2} \rho a V_1^{\,3}}$$

$$\eta_h - \frac{2[V_{w1} + V_{w2}] x\, u}{V_1^{\,2}}$$

$$\eta_h = \frac{[V_1 + (V_1 - u) \cos \emptyset - u]\ x\ u}{V_1^{\,2}}$$

$$\eta_h = \frac{2(V_1 - u)\ (1 + \cos \emptyset) x\, u}{V_1^{\,2}}$$

he efficiency is maximum when $\frac{d\,(\eta_h)}{du} = 0$

$$\frac{d}{du}\left[\frac{2(V_1 - u)\ (1 + \cos \emptyset) x\, u}{V_1^{\,2}}\right] = 0$$

$$\frac{(1 + \cos \emptyset)}{V_1^{\,2}}\ \frac{d}{du}[2u(V_1 - u] = 0$$

$$\frac{d}{du}[2uV_1 - 2u^2] = 0$$

$$u = \frac{V_1}{2}$$

Expression for maximum efficiency of pelton wheel

$$\eta_{h_{max}} = \frac{2(V_1 - \frac{V_1}{2})\,(1 + \cos\phi)x\,\frac{V_1}{2}}{{V_1}^2}$$

$$\eta_{h_{max}} = \frac{(1 + \cos\phi)}{2}$$

(1) Velocity of jet, $V_1 = C_v\sqrt{2gH}$

where, C_v = co-efficient of velocity = 0.98 to 0.99,

H = Net head on turbine

(2) Velocity of wheel, $u = K_u\sqrt{2gH}$

where K_u=speed ratio

Φ or Ku = 0.43 to 0.48

(3) Angle of deflection of the jet (φ) :

If no angle of deflection then it is 165 degr

(4) Mean diameter or pitch diameter of Pelton wheel (D)

$D = 60u/\pi N$

(5) Jet ratio (m) :

It is the ratio of the pitch diameter of Pelton wheel to the diameter of the jet (d).

$$m = D/d$$

6) Number of buckets (z) :

The no. of buckets for a pelton wheel should be such that water jet is always completely utilized by the buckets, so that no water from the jet should go waste.

$$z = 15+(D/2d)$$

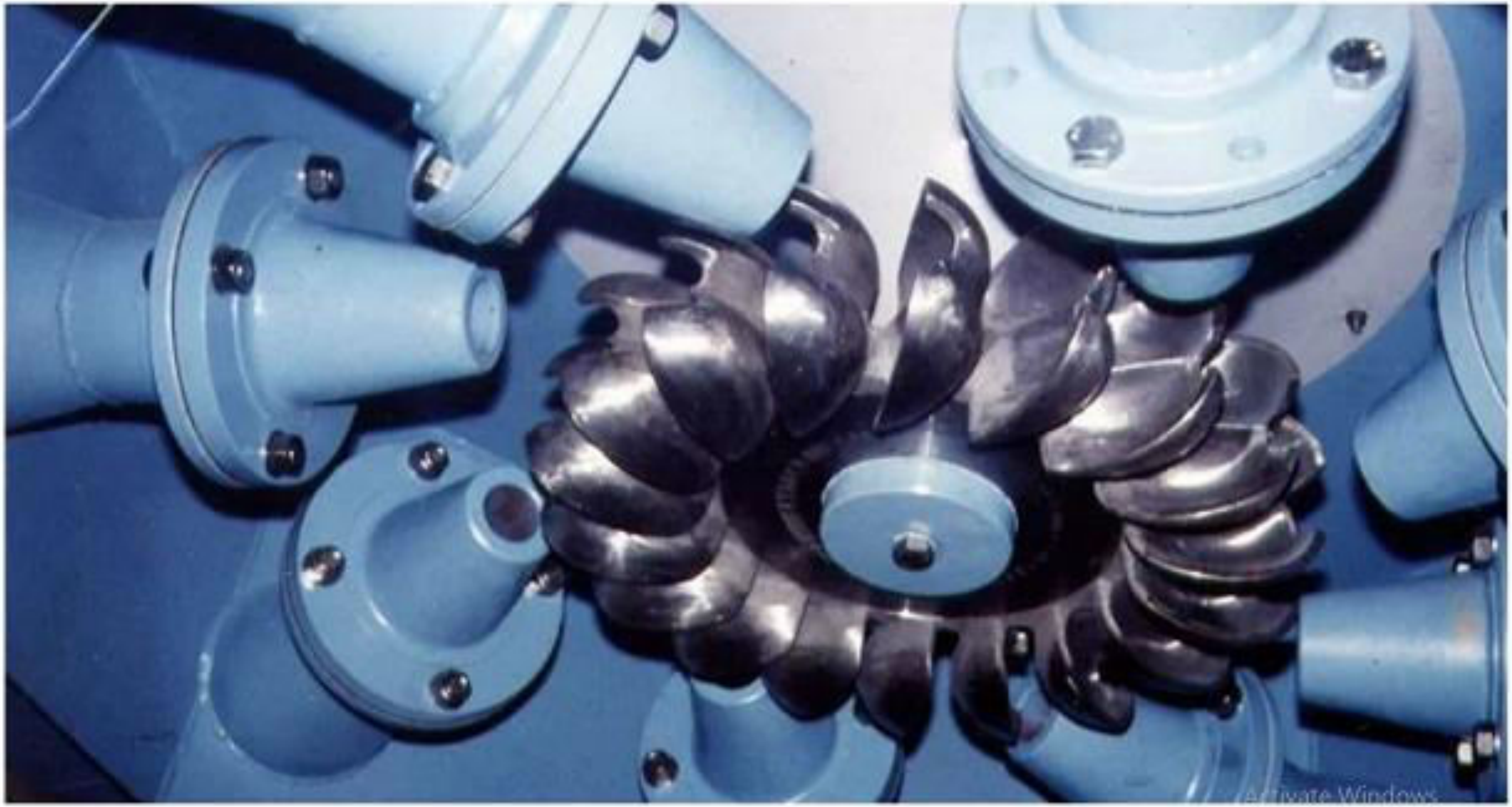
7) Number of jet (n) :

In pelton wheel normally one nozzle or jet is used. However, more than one nozzle may be employed when more power is to be produced with same wheel, but maximum no. of nozzle restricted to 6.

$$n = Q/q$$

(8) Dimensions of bucket :

Length = 2d to 3d, Width = 3d to 4d, Depth = 0.8 to 1.2d



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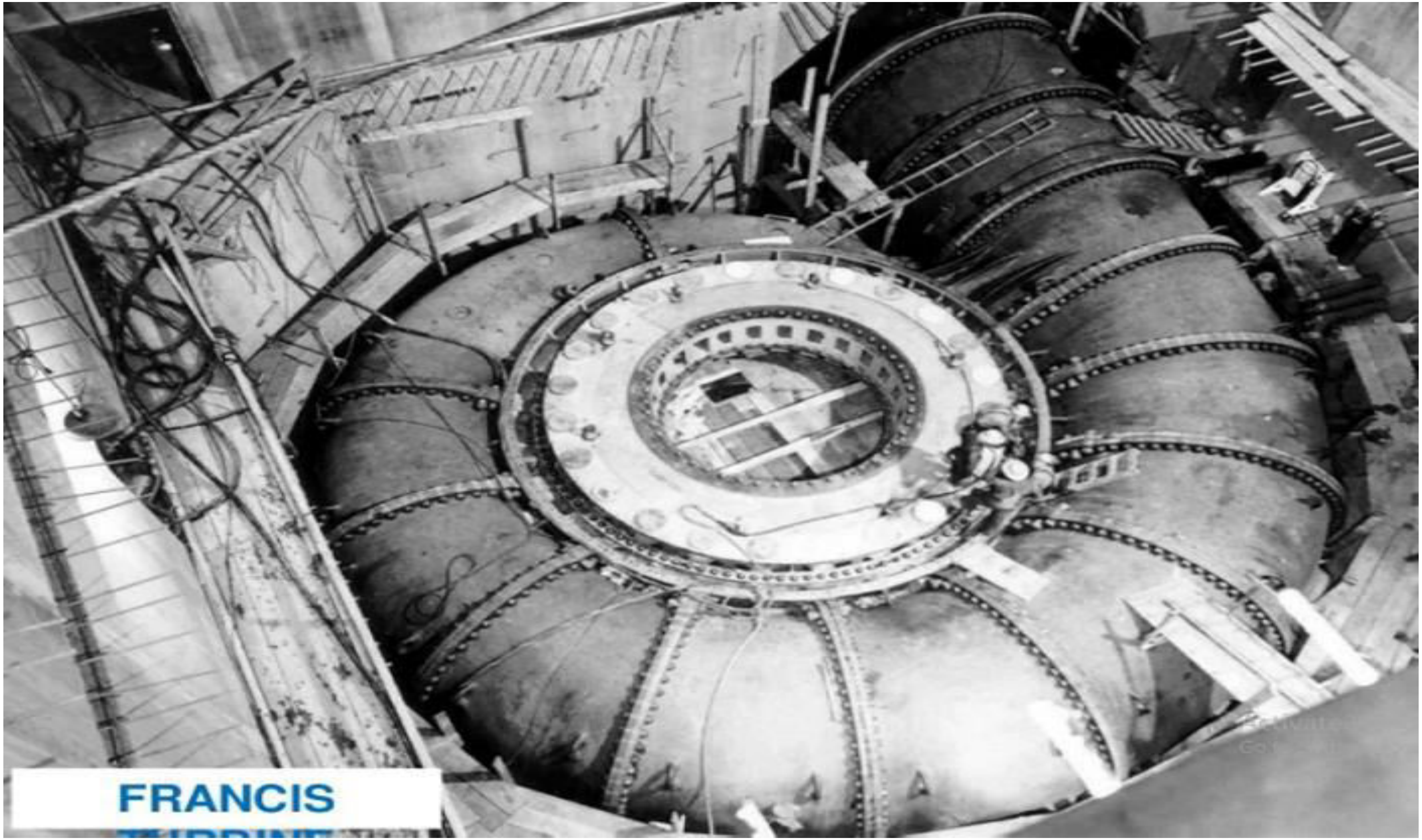
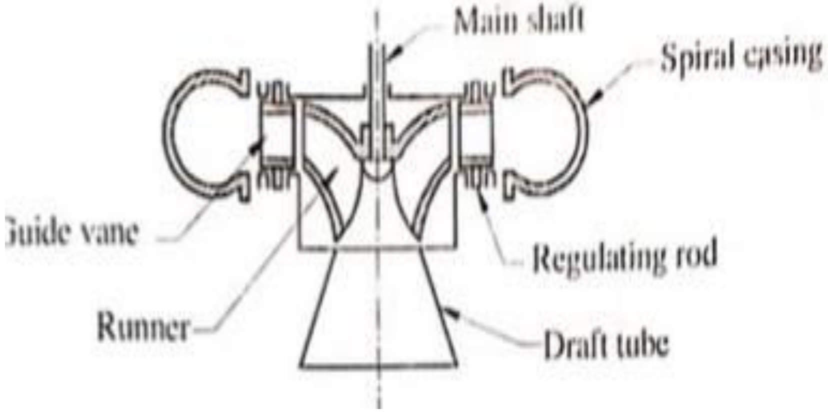
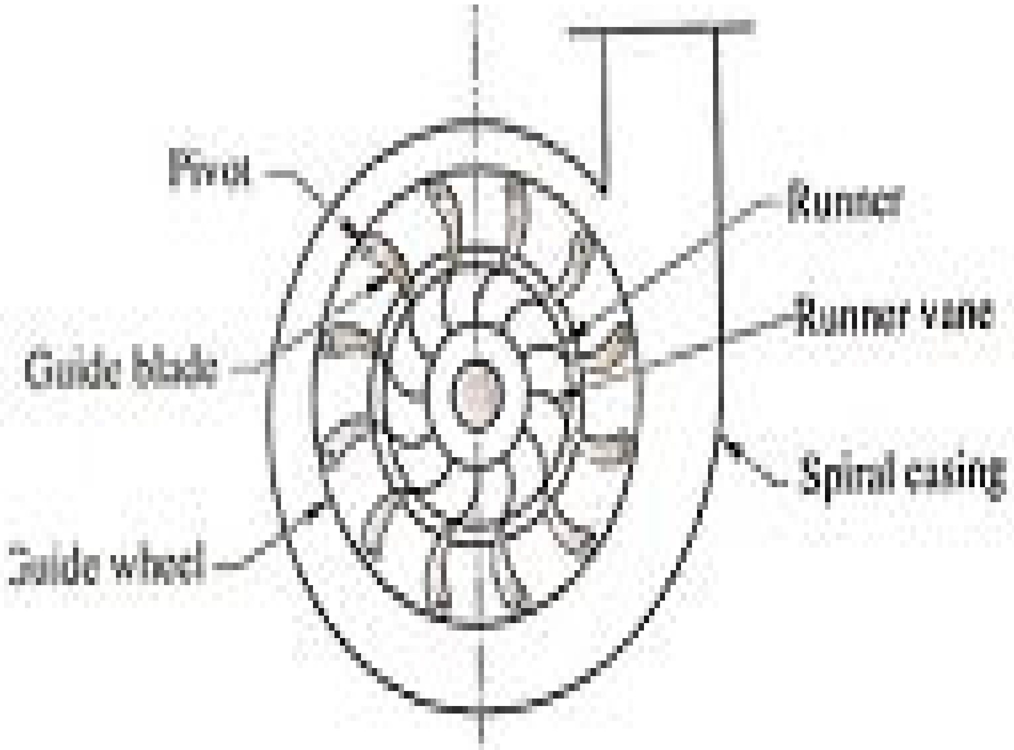
PELTON WHEEL WITH MULTILE JETS

The specific speed of turbine is defined as the speed of a geometrically similar turbine that would produce unit power under unit head at maximum efficiency.

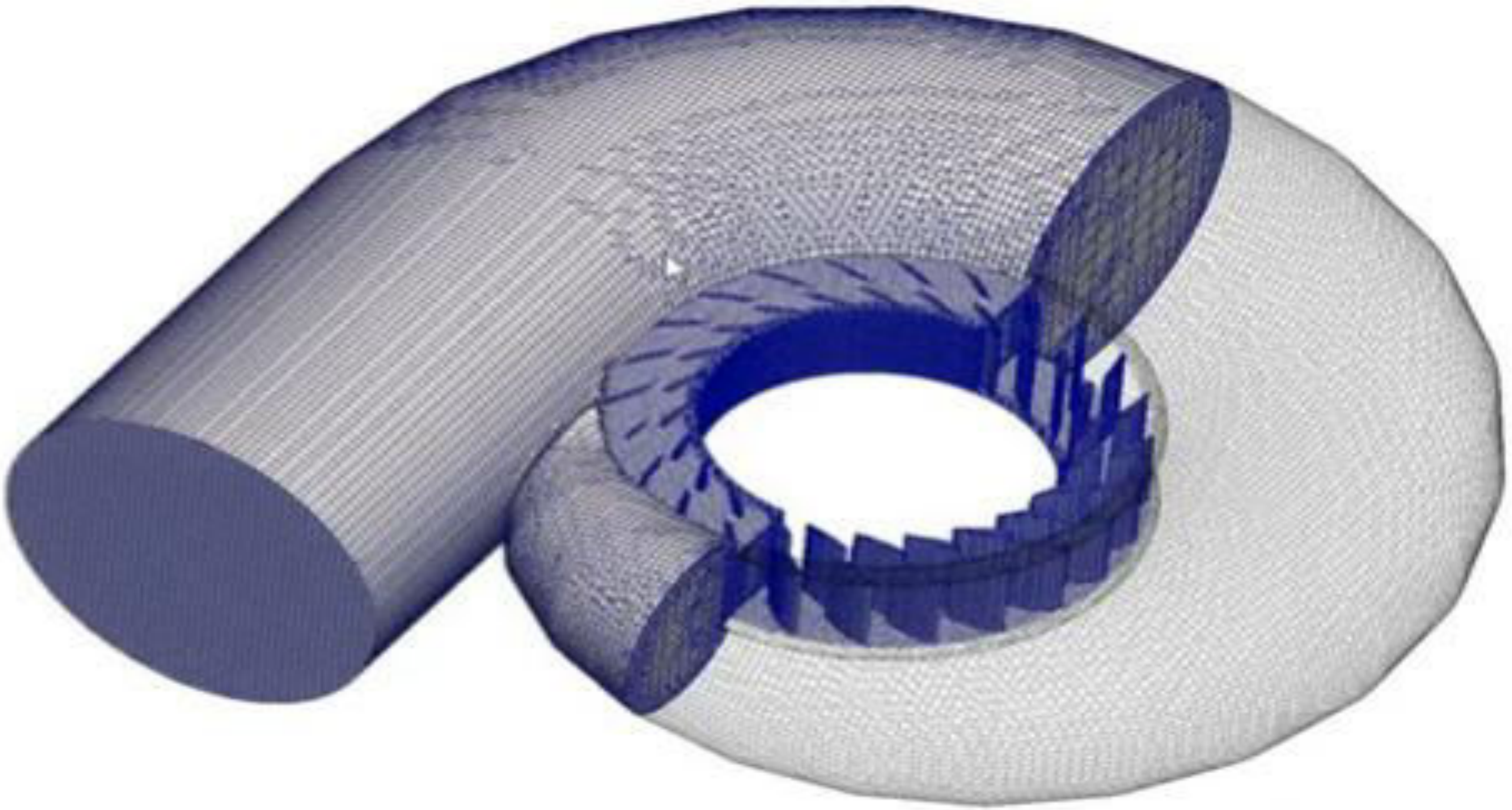

FRANCIS



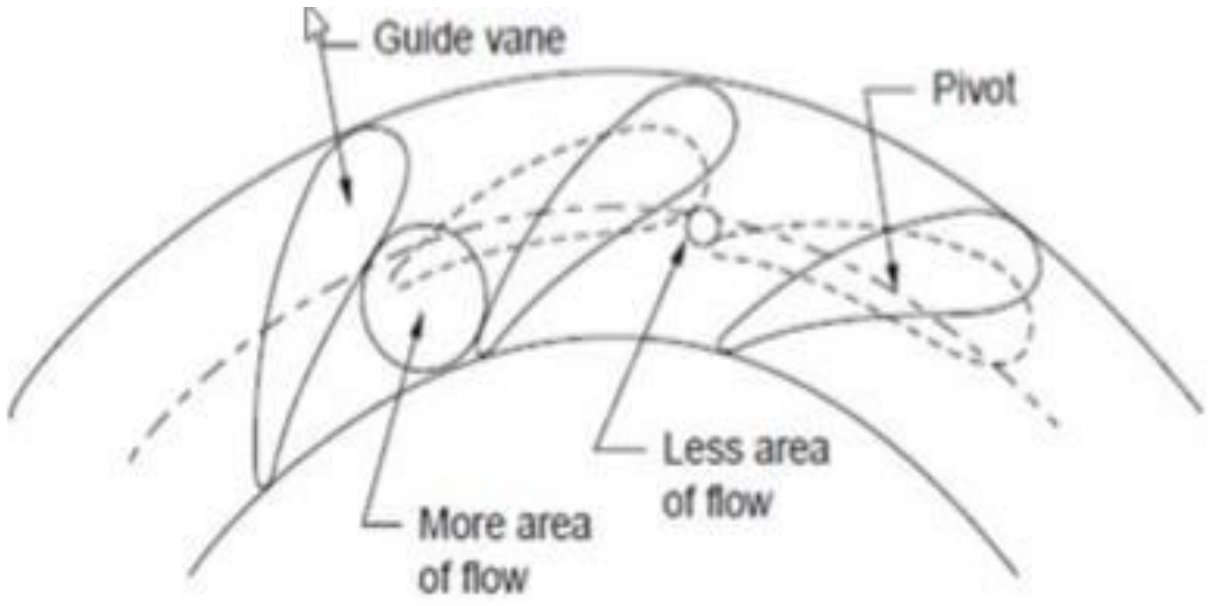


Components of Francis Turbine :

1) ***Penstock***
2) ***Spiral Casing***
3) ***Guide blade***
4) ***Runner***
5) ***Draft tube***



Guide Blades :



Runner :

It is most important component of francis turbine.

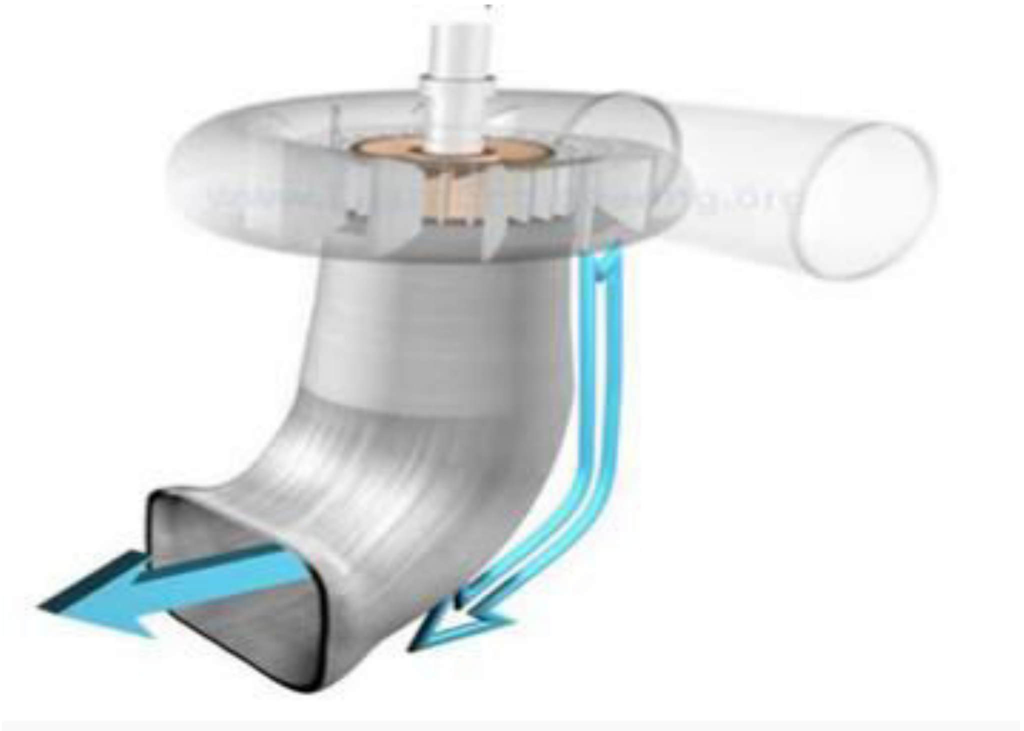
Water with high kinetic and pressure energy flows through the runner and makes runner to rotate and generates power.

In francis turbine runner the flow of water is combination of radial and axial.

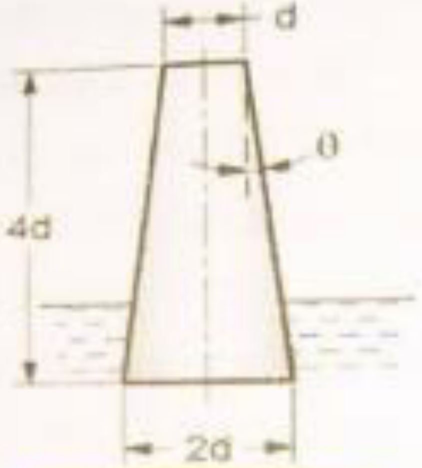
Enters radially inward and leaves in direction Parallel to axis of rotor.

Number of runner vanes 16 to 24.

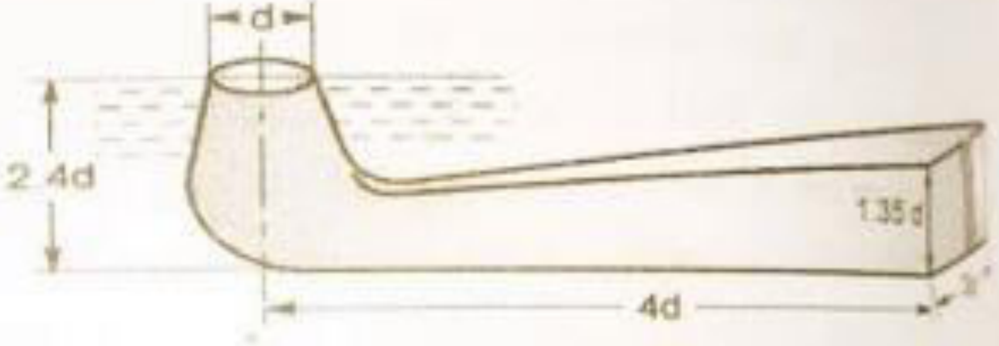
Draft tube :



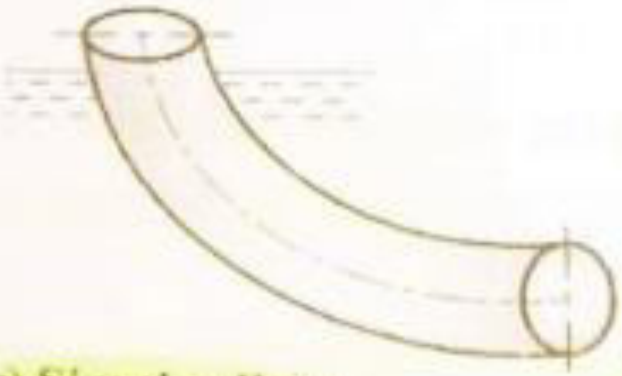
The draft tube is a pipe of gradually increasing area which connects the outlet of the runner to the tail race.

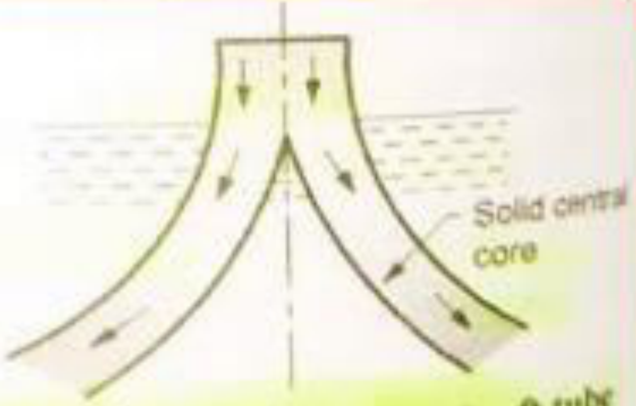


(a) Conical straight



(b) Elbow


(c) Simple elbow



(d) Moody's spreading draft tube