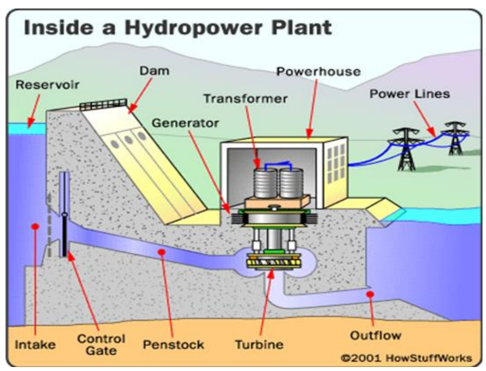
energy. The mechanical energy developed by the turbine is used in running an electric generator which is directly coupled to the shaft of the turbine. The electric generator thus generates electric power which is known as hydroelectric power.

- **Electric Motor:** Electric motor coverts electrical energy to mechanical energy.

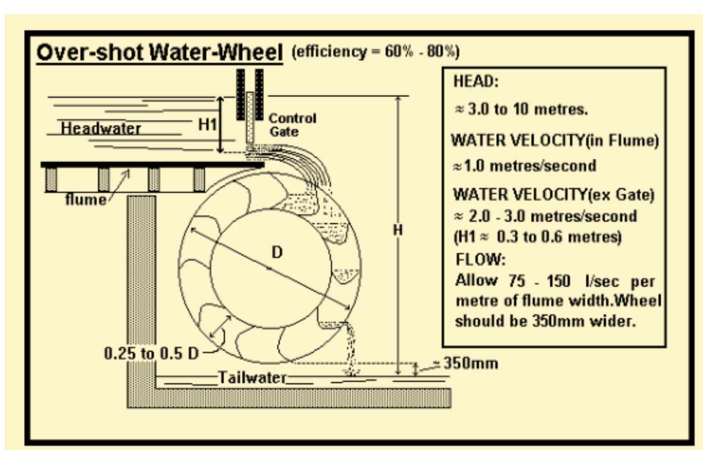
Unit-V: Hydraulic Turbines

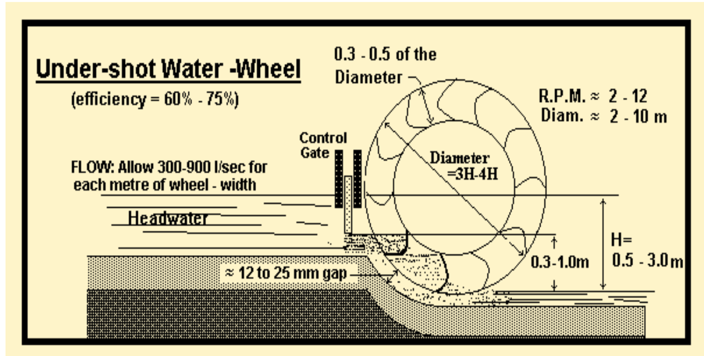
Introduction and Working principle of hydraulic turbines

- Hydraulic turbines are the machines which converts the hydraulic energy of water into mechanical energy. Therefore, these may be considered as hydraulic motors or prime movers.
- Pump: it converts mechanical energy into hydraulic energy. The mechanical energy developed by the turbine is used in running an electric generator which is directly coupled to the shaft of the turbine. The electric generator thus generates electric power which is known as hydroelectric power.
- Electric Motor: Electric motor coverts electrical energy to mechanical energy.



DEVELOPMENT OF TURBINES





■ In the early days of water, pump development water wheels made of wood are widely used which uses either (falling water) potential energy or kinetic energy of the flowing stream of water. The wheel consists of series of straight vanes on its periphery, water was permitted to enter at the top and imbalance created by the weight of the water causes wheel to rotate (over shot wheel uses potential energy, under short wheel uses kinetic energy). Since, the low efficiency and low power generation and these could not be directly coupled to modern fast electric generators for the purpose of power generation. Therefore, the water wheels are completely replaced by modern hydraulic turbines, which will run at any head and desired speed enabling the generator to be coupled directly.

■ In general turbine consists of wheel called runner or rotor having a number of specially developed vanes or blades or buckets. The water possessing large amount of hydro energy when strikes the runner, it does the work on runner and causes it to rotate.

<u>Classification of Hydraulic Turbines</u>

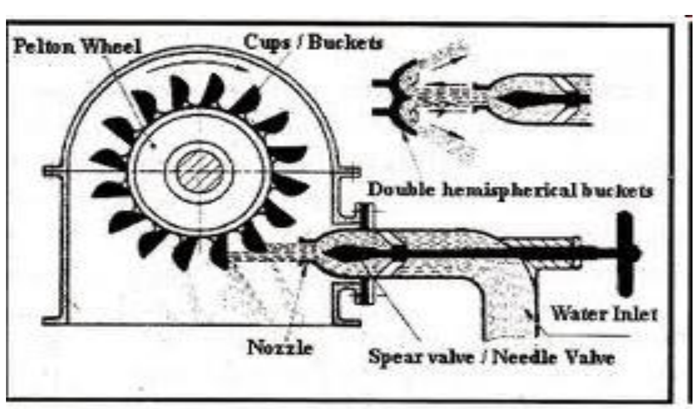
1. According to the type of energy at the inlet
2. According to the direction of flow through runner
3. According to head at inlet
4. According to specific speed of turbine
5. According to Position of the shaft

1. <u>According to the type of energy at the inlet</u>

a) Impulse turbine:

■ All the available energy of the water is converted into kinetic energy by passing it through a contracting nozzle provided at the end of penstock

Ex: Pelton wheel turbine, Turgo-impulse turbine, Girard turbine, Bank turbine, Jonval turbine etc.



b) Reaction Turbine:

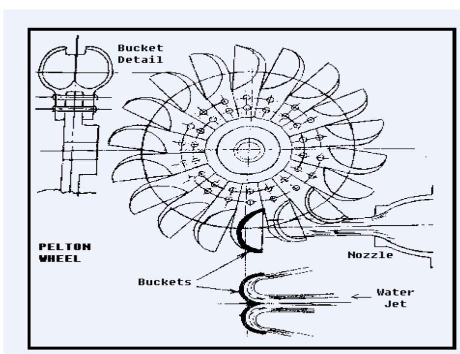
- At the entrance of the runner, only a part of the available energy of water is converted into kinetic energy and a substantial part remains in the form of pressure energy.
- As the water flow through the turbine pressure energy converts into kinetic energy gradually. Therefore the pressure at inlet of runner is higher than the pressure at outlet and it varies through out the passage of the turbine.
- For this gradual change of pressure to the possible the runner must be completely enclosed in a air-tight casing and the passage is entirely full of water throughout the operation of turbine
- The difference of pressure between the inlet and outlet of the runner is called reaction
- pressure and hence the turbines are known as reaction turbines.
- Ex: Francis turbine, Kaplan turbine, Thomson Turbine, Fourneyron turbine, Propeller turbine, etc

2. <u>According to the direction of flow through runner:</u>

a) Tangential flow turbine	b) Radial flow turbine
c) Axial flow turbine	d) Mixed flow turbine

a) Tangential flow turbine:

The water flows along the tangent to the path of rotation of the runner
Ex: Pelton wheel turbine



b) Radial flow Turbine

- The water flows in the radial direction through the runner.
- <u>Inward radial flow turbine:</u> The water enters the outer circumference and flows radially inwards towards the centre of the runner.
- Ex: Old Francis turbine, Thomson turbine, Girard turbine etc

■ Outward radial flow turbine: The water enters at the centre and flows radially outwards towards the outer periphery of the runner.

■ Ex: Fourneyron turbine.

c) Axial flow turbine:

■ The water flow through runner wholly and mainly along the direction parallel to the axis of rotation of the runner.

■ Ex: Kaplan turbine, Jonval, Girard axial flow turbine, Propeller turbine, etc

d) Mixed flow turbines

The water enters the runner at the outer periphery in the radial direction and leaves it at the centre of the axial direction parallel to the rotation of the runner.

Ex: Modern Francis turbine.

3. According to head at inlet:

a) High head turbines: These turbines work under very high heads 255m - 1770m and above. Requires relatively less quantity of water.

Ex: Pelton wheel turbine or impulse turbine.

b) Medium head turbines: These turbines are capable of working under medium heads ranging from 60m - 250m These turbines requires large quantity of water.

Ex: Francis Turbine

c) Low head turbines: these turbines are capable of working under the heads less than 60mts.

These turbines requires large quantity of water.

Ex: Kaplan turbine, propeller turbine.

a) Low specific speed turbines: specific speed turbine varies from 8.5 to 30.

Ex: Pelton wheel turbine

b) Medium specific speed turbines: specific speed varies from 50 to 340

Ex: Francis turbine.

c) High specific speed turbines: specific speed varies from 255-860.

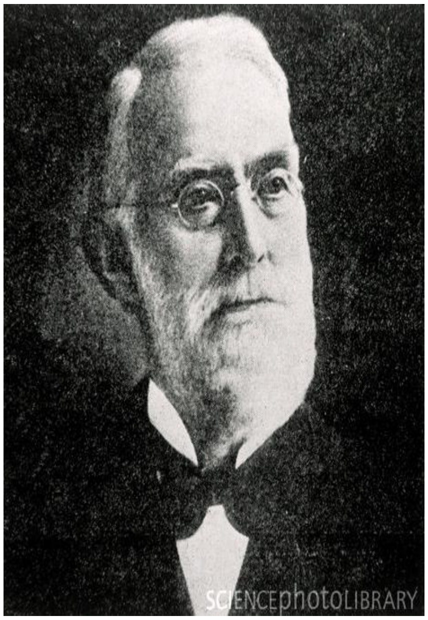
Ex: Kaplan and propeller turbine.

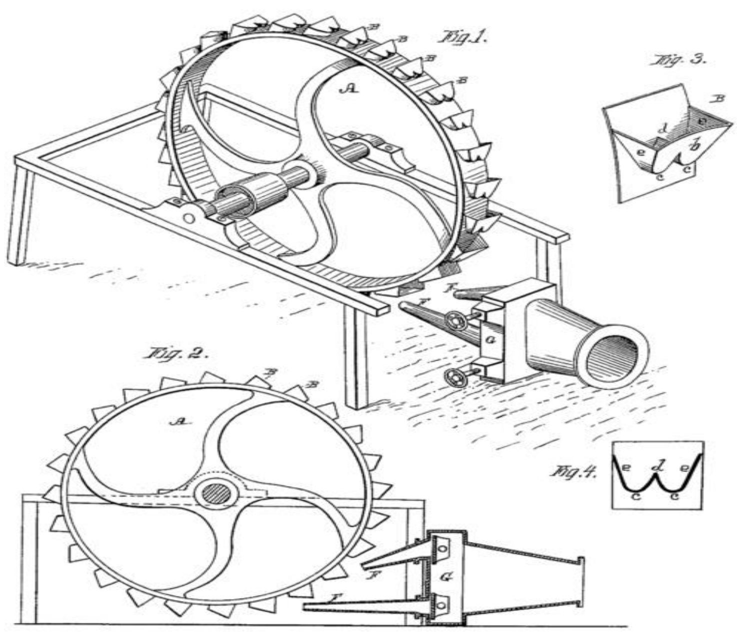
5) According to the position of the shaft:

a) Horizontal disposition of shaft

b) Vertical disposition of shaft.
Turbine Shaft

PELTON WHEEL TURBINE





- This is named after Lester A. Pelton, American engineer who contributed much to its development in about 1880. It is well suited for operating under high heads.
- It's an impulse, high head, low specific speed and tangential flow turbine.
- The runner consists of a circular disc with a number of buckets evenly spaced around its periphery.

- The buckets have a shape of double semi-ellipsoidal cups. Each bucket is divided into 2 symmetrical parts by sharp edged ridge known as splitter.
- One or more nozzles are mounted so that each directs a jet along a tangential to the pitch circle of runner or axis of blades.
- The jet of water impinges on the splitter, which divides jet into equal halves, each of which after flowing around the smooth inner surface of the bucket leaves at its outer edge.

- The buckets are so shaped that the angle at the outlet lip varies from 10 to 20 degrees. So that the jet of outer deflects through 160 to 170. The advantage of having double cup-shaped bucket is that the axial thrust neutralizes each other being equal and opposite and having bearing supporting the wheel shaft are not supported to any axial thrust or end thrust.

■The back of the bucket is shaped that as it swings downward into the jet no water is wasted by splashing.

■At the lower tips of the bucket a notch is cut which prevents the jet striking the preceding bucket and also avoids the deflection of water towards the centre of the wheel.

■For low heads buckets are made of C.I, for high heads buckets are made of Cast Steel ,bronze, stainless steel.

■In order to control the quantity of water striking the runner, the nozzle is fitted at the end of the penstock is provided with a spear valve having streamlined head which is fixed at the end of the rod.

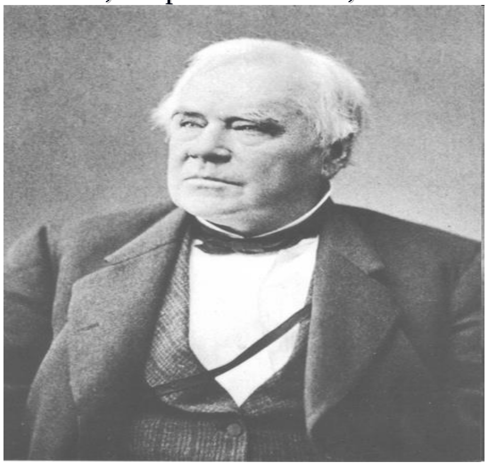
■When the shaft of pelton wheel is horizontal, not more than to two jets are used if the shaft vertical six number of jets are possible.

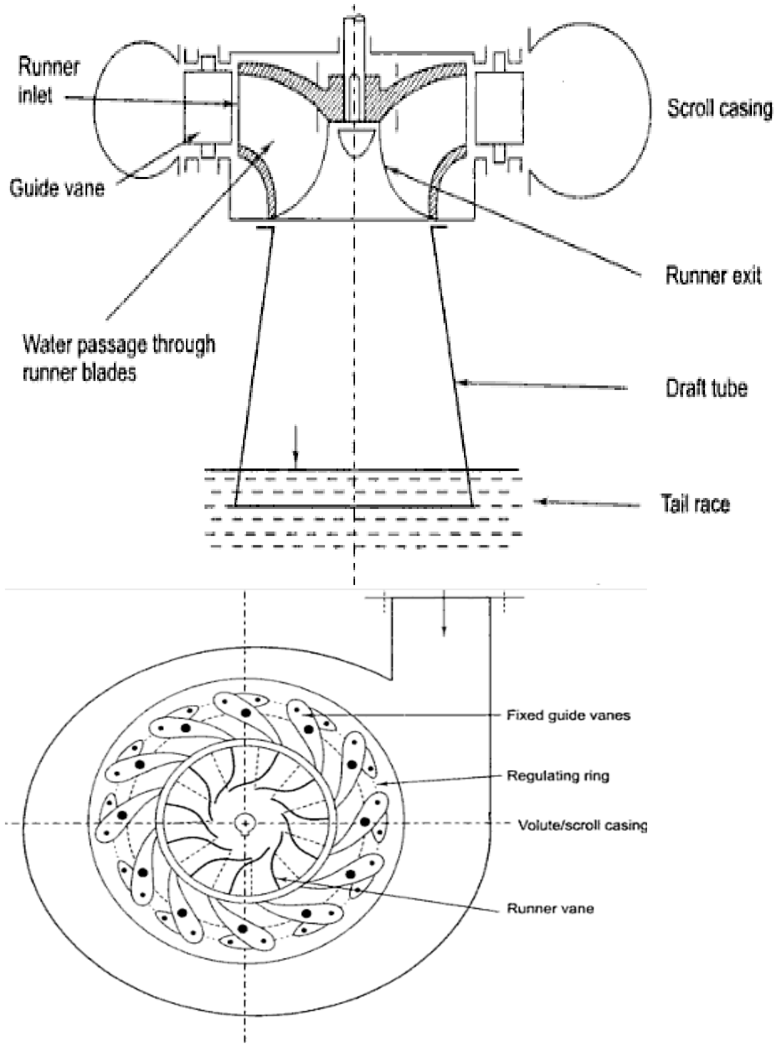
■A casing is made of C.I or fabricated steel plates is usually provided for a pelton wheel to prevent splashing of water, to lead water to the tail race and also act as safeguard against accidents.

■Large pelton wheels are usually equipped with a small break nozzle which when opened directs a jet of water on the back of the buckets, therby bringing the wheel quickly to rest after it is shut down, otherwise it takes considerable time to come to rest.

REACTION TURBINES:

■In reaction turbines, the available energy of water at inlet of the turbine is sum of pressure energy and kinetic energy and during the flow of water through the runner a part of pressure energy is converted into kinetic energy, such type of turbine is reaction turbine. Ex: Francis Turbine, Kaplan Turbine, Propeller Turbine, etc





Sectional view of Francis Turbine

The main components of Francis Turbine:

Scroll Casing:

- The water from the penstock enters the scroll casing or spiral casing which completely surrounds the runner. The purpose of casing is to provide even distribution of water around the circumference of the runner and to maintain constant velocity of water so distributed.

- In order to maintain constant velocity of water through out its path around the runner, the cross-sectional area of casing is gradually decreased. The casing is made of cast steel or plate steel.

2. Stay Ring:

-From the scroll casing the water passes through a speed ring or stray ring. Stay ring consists of outer and lower ring held together by series of fixed vanes called stay vanes.

- Number of stay vanes usually half of the number of guide vanes. Stay vane performs two functions, one is to direct the water from the scroll casing to the guide vanes and other is to rest the load imposed upon it by the internal pressure of water and the weight of the turbine and electrical generator and transmits the same to the foundation. Speed ring is made of C.I or C.S.

3. Guide Vanes:

-From the stay ring water passes through a series of guide vanes provided around the periphery of the runner. The function of guide vanes is to regulate the quantity of water supplied to the runner and to direct the water on to the runner with design angle.

- The guide vanes are airfoil shaped and made of C.S or S.S or P.S. Each guide vane is provided with two stems; the upper stem passes through head cover and lower stem seats in bottom ring. By a system of levers and links all the guide vanes may be turned about their stems, so as to alter the width of the passage between the adjacent guide vanes, thereby allowing a variable quantity of water to strike the runner. The guide vanes are operated either by means of a wheel or automatically by a governor.

4. RUNNER:

-The runner of a Francis turbine consists of a series of a curved vanes (from 16 to 24) evenly arranged around the circumference in the annular space between two plates.

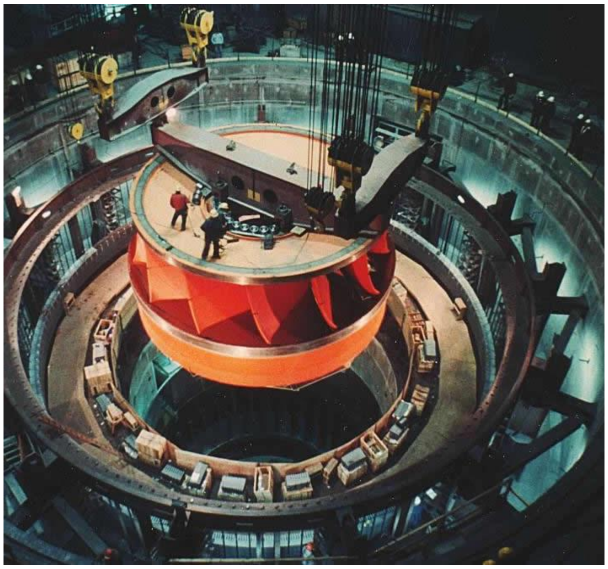
-The vanes are so shaped that water enters the runner radially at the outer periphery and leaves it axially at the inner periphery.

-The change in the direction of flow of water from radial to axial, as it passes through the runner, produces a circumferential force on the runner which makes the runner to rotate and thus contributes to the useful output of the runner.

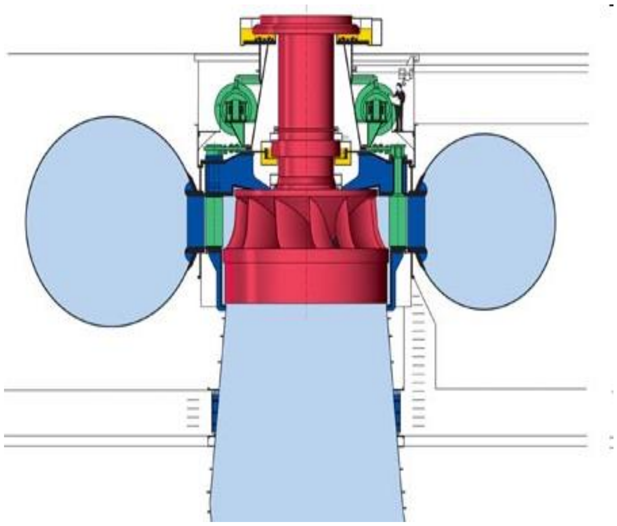
-Runner vanes are made of SS and other parts are made of CI or CS

- The runner is keyed to a shaft which is usually of forged steel. The torque produced by the runner is transmitted to the generator through the shaft which is usually connected to the generator shaft by a bolted flange connection.

Francis turbine installation:



KAPLAN TURBINE



Prof. Viktor Kaplan, Austrian inventor of the Kaplan Turbine, 1913

- Kaplan turbine is developed by the Austrian Engineer Viktor Kaplan, it is suitable for low heads and requires large quantity of water to develop large amount of power. Since it is a reaction turbine, it operates in an entirely closed conduit from head race to tail race.

- The main components of a Kaplan turbine
- **Scroll Casing**
- **Guide vanes Mechanism**
- **Hub with vanes or runner of turbine, and**
- **Draft Tube**

- The function of above components is same as that of Francis turbine

- The water from the penstock enters the scroll casing and then moves to the guide vanes. From the guide vanes, the water turns through 900 and flows axially through the runner.

- The runner of a Kaplan turbine has four or six blades (eight in exceptional cases). The blades attached to a hub are so shaped that water flows axially through the runner.

- The adjustment of the runner blades is usually carried out automatically by means of a servomotor operating inside the hollow coupling of turbine and generator shaft.

- When both guide vane angle and runner blade angle may varied, a high efficiency can be maintained. Even at part load, when a lower discharge is flowing through the runner, a high efficiency can be attained in case of Kaplan turbine.

- Simultaneously the guide vane and runner vane angles are adjusted the water under all the working conditions flows through the runner blades without shock. as such the eddy losses which inevitable in Francis turbine and propeller turbines are almost completely eliminated in a Kaplan turbine.