(Lecture 1)

REACTION TURBINES:-

Lecture contains

- Introduction
- Francis Turbine

REACTION TURBINES:-

- Reaction turbine means that the water at the inlet of the turbine possesses kinetic energy as well as pressure energy

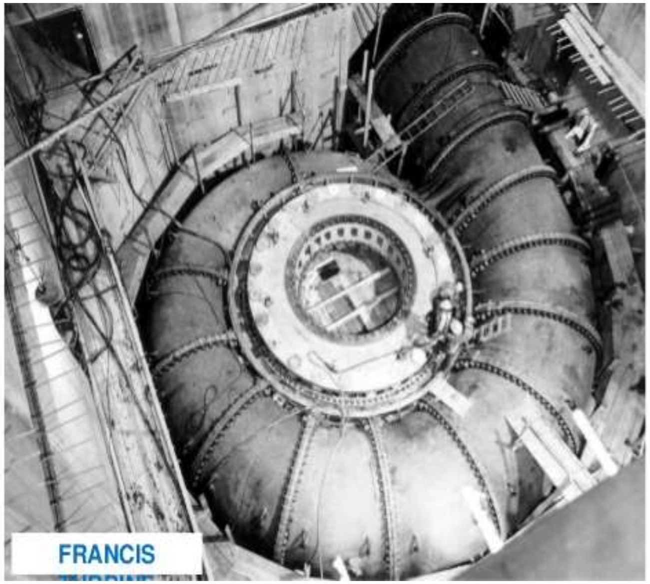
- The principal distinguishing features of a reaction turbine are that only part of the total head of water is converted into velocity head before it reaches the runner, and that the water completely fills all the passage in the runner.

- The pressure of water changes gradually as it passes through the runner.

- The two reaction type of turbines which are predominantly used these days are Francis turbine and Kaplan turbine

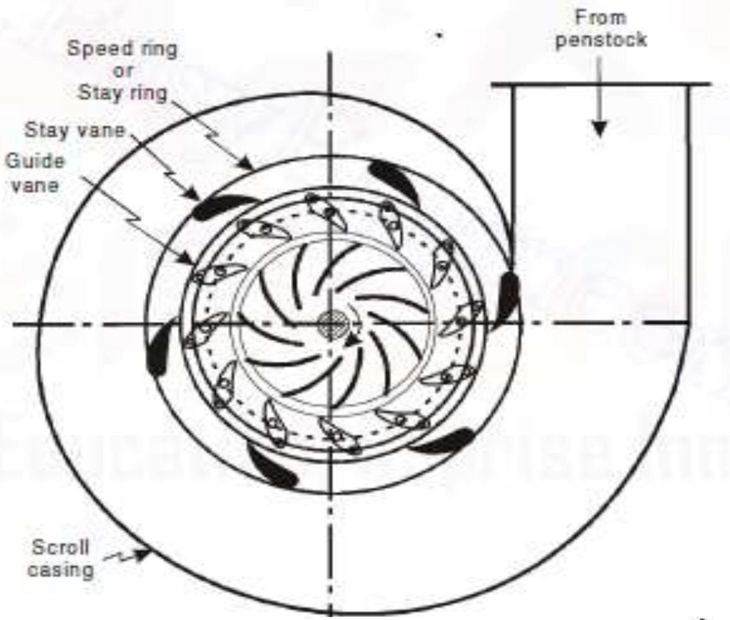
Francis turbine:-

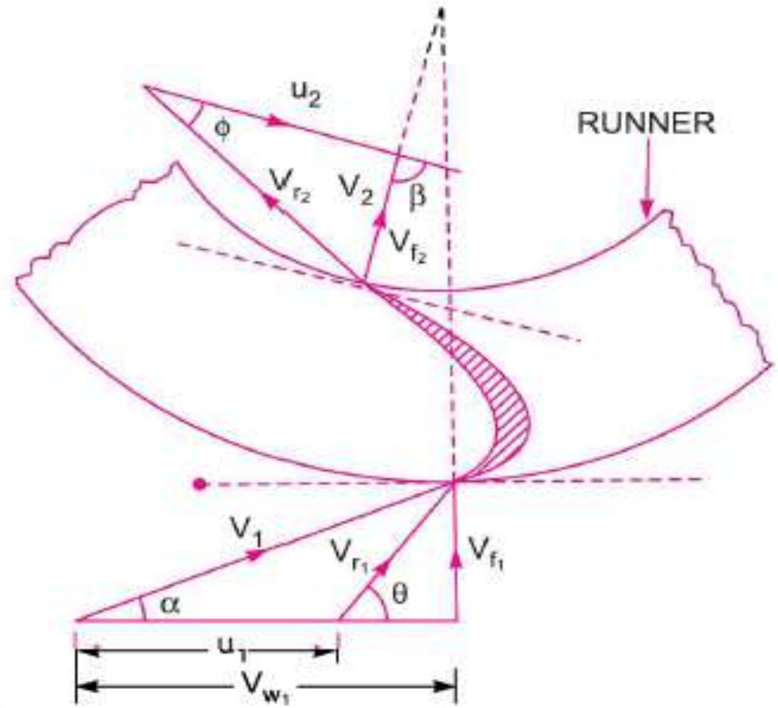
Francis turbine which is a mixed flow type of reaction turbine. It is named in honour of James B. Francis (1815–92), an American Engineer, who was the first to develop an inward radial flow type of reaction turbine in 1849. Later on it was modified and the modern Francis turbine is a mixed flow type, in which water enters the runner radially at its outer periphery and leaves axially at its centre.

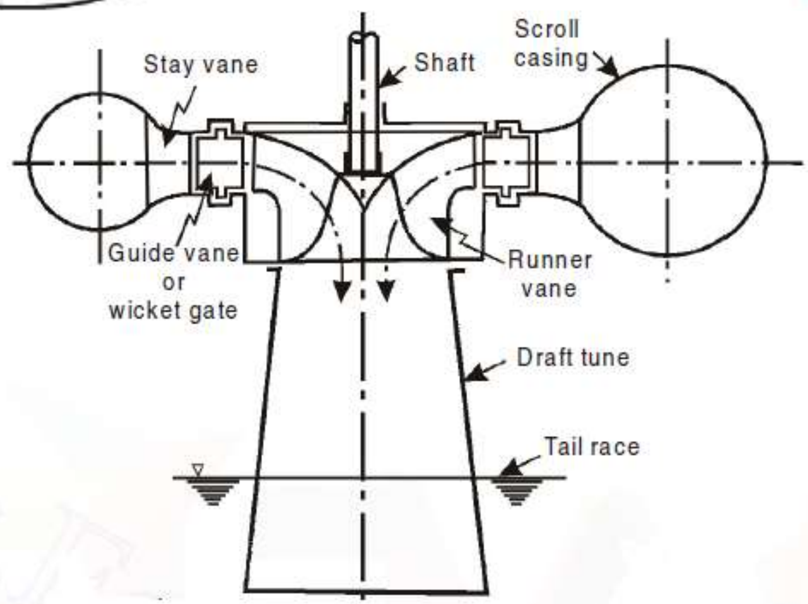


FRANCIS TURBINE

Velocity triangle, work done and efficiency of Francis Turbine:-







Velocity triangle, work done and efficiency of Francis Turbine:-

The work done per second on the runner by water is given by equation (17.26) as

$$= \rho a V_1 [V_{w_1} u_1 \pm V_{w_2} u_2]$$

$$= \rho Q [V_{w_1} u_1 \pm V_{w_2} u_2] \qquad (\because \quad aV_1 = Q) \quad ...(1 \quad)$$

The equation (18.18) also represents the energy transfer per second to the runner.

where V_{w_1} = Velocity of whirl at inlet,

V_{w_2} = Velocity of whirl at outlet,

u_1 = Tangential velocity of wheel at inlet

$= \frac{\pi D_1 \times N}{60}$, where D_1 = Outer dia. of runner,

u_2 = Tangential velocity of wheel at outlet

$= \frac{\pi D_2 \times N}{60}$, where D_2 = Inner dia. of runner, N = Speed of the turbine in .r.p.m.

The work done per second per unit weight of water per second.

$$= \frac{\text{Work done per second}}{\text{Weight of water striking per second}}$$

$$= \frac{\rho Q \left[V_{w_1} u_1 \pm V_{w_2} u_2\right]}{\rho Q \times g} = \frac{1}{g}\left[V_{w_1} u_1 \pm V_{w_2} u_2\right] \qquad ...(2 \quad)$$

Velocity triangle, work done and efficiency of Francis Turbine:-

The equation (2) represents the energy transfer per unit weight/s to the runner. This equation is known by **Euler's equation** of hydrodynamics machines. This is also known as fundamental equation of hydrodynamic machines. This equation was given by Swiss scientist *L.* Euler.

In equation (2), +ve sign is taken if angle β is an acute angle. If β is an obtuse angle then –ve sign is taken. If β = 90°, then $V_{w_2} = 0$ and work done per second per unit weight of water striking/s become as

$$= \frac{1}{g} V_{w_1} u_1$$

Hydraulic efficiency is obtained

$$\eta_h = \frac{\text{R.P.}}{\text{W.P.}} = \frac{\frac{W}{1000g}[V_{w_1} u_1 \pm V_{w_2} u_2]}{\frac{W \times H}{1000}} = \frac{(V_{w_1} u_1 \pm V_{w_2} u_2)}{gH}$$

where R.P. = Runner power *i.e.*, power delivered by water to the runner

W.P. = Water power

If the discharge is radial at outlet, then $V_{w_2} = 0$

$$\eta_h = \frac{V_{w_1} u_1}{gH}$$

Hydraulic Machines BME-51
Unit-2

(Lecture 2)

Lecture contains

- Design of Francis Turbine
- Degree of reaction

Design of Francis Turbine:-

(*i*) **Speed Ratio.** The speed ratio is defind as = $\frac{u_1}{\sqrt{2gH}}$
where u_1 = Tangential velocity of wheel at inlet.

(*ii*) **Flow Ratio.** The ratio of the velocity of flow at inlet (V_{f_1}) to the velocity given $\sqrt{2gH}$ is known as flow ratio or it is given as

$$= \frac{V_{f_1}}{\sqrt{2gH}}, \text{ where } H = \text{Head on turbine}$$

(*iii*) **Discharge of the Turbine.** The discharge through a reaction radial flow turbine is given by

$$Q = \pi D_1 B_1 \times V_{f_1} = \pi D_2 \times B_2 \times V_{f_2} \quad ...(1)$$

where D_1 = Diameter of runner at inlet,
B_1 = Width of runner at inlet,
V_{f_1} = Velocity of flow at inlet, and
D_2, B_2, V_{f_2} = Corresponding values at outlet.

If the thickness of vanes are taken into consideration, then the area through which flow takes place is given by $(\pi D_1 - n \times t)$
where n = Number of vanes on runner and t = Thickness of each vane

The discharge Q, then is given by $Q = (\pi D_1 - n \times t)\, B_1 \times V_{f_1}$ ...(2)

(*iv*) The head (H) on the turbine is given by $H = \frac{p_1}{\rho \times g} + \frac{V_1^2}{2g}$ ...(3)

where p_1 = Pressure at inlet.

(*v*) **Radial Discharge.** This means the angle made by absolute velocity with the tangent on the wheel is 90° and the component of the whirl velocity is zero. Radial discharge at outlet means $\beta = 90°$ and $V_{w_2} = 0$, while radial discharge at outlet means $\alpha = 90°$ and $V_{w_1} = 0$.

Design of Francis Turbine cont….

Important Relations for Francis Turbines. The following are the important relations for Francis Turbines :

1. The ratio of width of the wheel to its diameter is given as $n = \frac{B_1}{D_1}$. The value of n varies from 0.10 to .40.

2. The flow ratio is given as,

Flow ratio = $\frac{V_{f_1}}{\sqrt{2gH}}$ and varies from 0.15 to 0.30.

3. The speed ratio = $\frac{u_1}{\sqrt{2gH}}$ varies from 0.6 to 0.9.

Problem *A Francis turbine with an overall efficiency of 75% is required to produce 148.25 kW power. It is working under a head of 7.62 m. The peripheral velocity = 0.26 $\sqrt{2gH}$ and the radial velocity of flow at inlet is $0.96\sqrt{2gH}$. The wheel runs at 150 r.p.m. and the hydraulic losses in the turbine are 22% of the available energy. Assuming radial discharge, determine :*

(i) The guide blade angle, *(ii) The wheel vane angle at inlet,*
(iii) Diameter of the wheel at inlet, and *(iv) Width of the wheel at inlet.*

Problem *The following data is given for a Francis Turbine. Net head H = 60 m ; Speed N = 700 r.p.m.; shaft power = 294.3 kW ; η_o = 84% ; η_h = 93%; flow ratio = 0.20 ; breadth ratio n = 0.1; Outer diameter of the runner = 2 × inner diameter of runner. The thickness of vanes occupy 5% of circumferential area of the runner, velocity of flow is constant at inlet and outlet and discharge is radial at outlet. Determine :*

(i) Guide blade angle, *(ii) Runner vane angles at inlet and outlet,*
(iii) Diameters of runner at inlet and outlet, and *(iv) Width of wheel at inlet.*

Example *Design a Francis turbine runner with the following data: Net head H = 68 m; speed N = 750 r.p.m; output power P = 330 kW; η_h = 94%; η_0 = 85 %; flow ratio ψ = 0.15; breadth ratio n = 0.1; inner diameter of runner is $\left(\frac{1}{2}\right)$ outer diameter. Also assume 6% of circumferential area of the runner to be occupied by the thickness of the vanes. Velocity of flow remains constant throughout and flow is radial at exit.*

Degree of reaction:-

Degree of reaction ρ, is defined as the ratio of pressure drop in the runner to the hydraulic work done on the runner. Thus is *p and p_1 are the pressures at the inlet and the outlet of the runner, then*

$$\rho = \frac{\left(\frac{p}{w} - \frac{p_1}{w}\right)}{\frac{V_w u - V_{w_1} u_1}{g}}$$

and if $V_{w_1} = 0$, then

$$\rho = \frac{\left(\frac{p}{w} - \frac{p_1}{w}\right)}{\frac{V_w u}{g}}$$

for no loss of head in the runner the degree of reaction can be expressed in terms of guide vane and runner vane angles. Thus for a given runner and set of guide vanes the degree of reaction is more or less constant if there is no loss of head in the runner. However, in actual practice because of the head loss in the runner the degree of reaction is not constant.

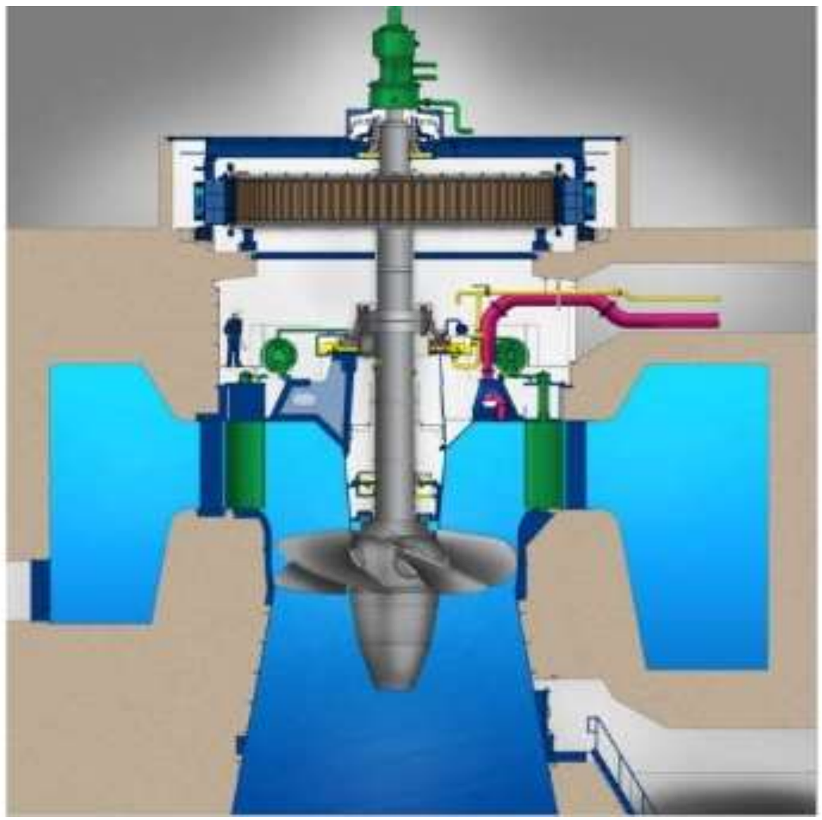
(Lecture 3)

Lecture contains

- Kaplan Turbine

Kaplan Turbine:-

A Kaplan turbine is a type of propeller turbine which was developed by the Austrian engineer V. Kaplan (1876–1934). It is an axial flow turbine, which is suitable for relatively low heads, and hence requires a large quantity of water to develop large amount of power. It is also a reaction type of turbine and hence it operates in an entirely closed conduit from the head race to the tail race.



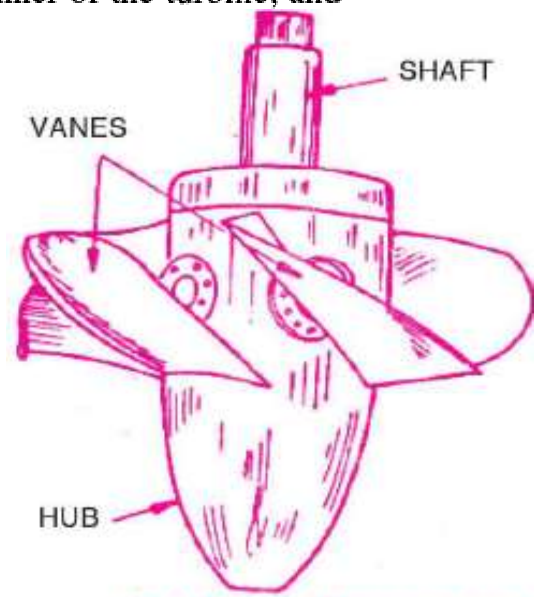
KAPLAN TURBINE

Kaplan Turbine:-

When the vanes are fixed to the hub and they are not adjustable, the turbine is known as propeller turbine. But if the vanes on the hub are adjustable, the turbine is known as a *Kaplan Turbine*, after the name of V Kaplan, an Austrian Engineer. This turbine is suitable where a large quantity of water at low head is available. Fig. shows the runner of a Kaplan turbine, which consists of a hub fixed to the shaft. On the hub, the adjustable vanes are fixed as shown in Fig.

The main parts of a Kaplan turbine are :

1. Scroll casing,
2. Guide vanes mechanism,
3. Hub with vanes or runner of the turbine, and
4. Draft tube.



Kaplan turbine runner.

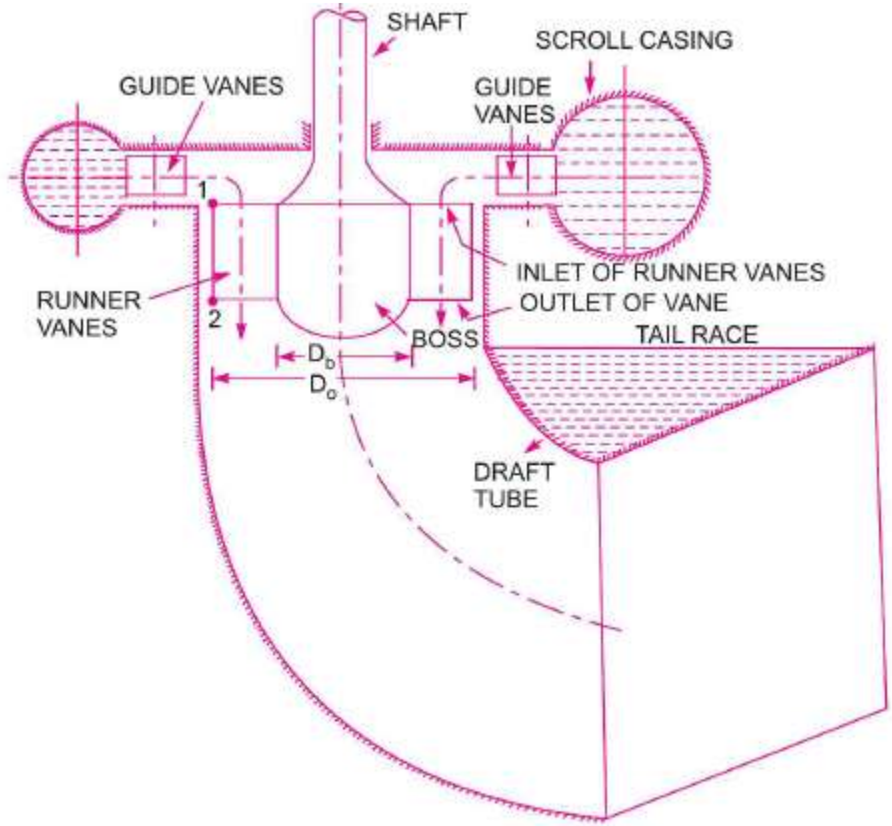
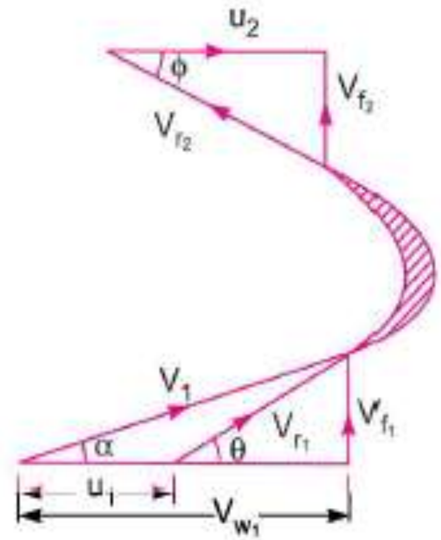


Fig. *Main components of Kaplan turbine.*

Kaplan Turbine:-



$$Q = \frac{\pi}{4}\left(D_o^2 - D_b^3\right) \times V_{f_1}$$

where D_o = Outer diameter of the runner,

D_b = Diameter of hub, and

V_{f_1} = Velocity of flow at inlet.

Some Important Point for Propeller (Kaplan Turbine). The following are the important points for propeller or Kaplan turbine :

1. The peripheral velocity at inlet and outlet are equal

$\therefore$ $$u_1 = u_2 = \frac{\pi D_o N}{60}, \text{ where } D_o = \text{Outer dia. of runner}$$

2. Velocity of flow at inlet and outlet are equal

$\therefore$ $$V_{f_1} = V_{f_2}.$$

3. Area of flow at inlet = Area of flow at outlet

$$= \frac{\pi}{4}\left(D_o^2 - D_b^2\right).$$

Kaplan Turbine:-

Problem *A Kaplan turbine working under a head of 20 m develops 11772 kW shaft power. The outer diameter of the runner is 3.5 m and hub diameter is 1.75 m. The guide blade angle at the extreme edge of the runner is 35°. The hydraulic and overall efficiencies of the turbines are 88% and 84% respectively. If the velocity of whirl is zero at outlet, determine :*

(i) Runner vane angles at inlet and outlet at the extreme edge of the runner, and

(ii) Speed of the turbine.

Problem *The hub diameter of a Kaplan turbine, working under a head of 12 m, is 0.35 times the diameter of the runner. The turbine is running at 100 r.p.m. If the vane angle of the extreme edge of the runner at outlet is 15° and flow ratio is 0.6, find :*

(i) Diameter of the runner, *(ii) Diameter of the boss, and*

(iii) Discharge through the runner.

The velocity of whirl at outlet is given as zero.

(Lecture 4)

Lecture contains

- Draft Tube

Draft Tube:-

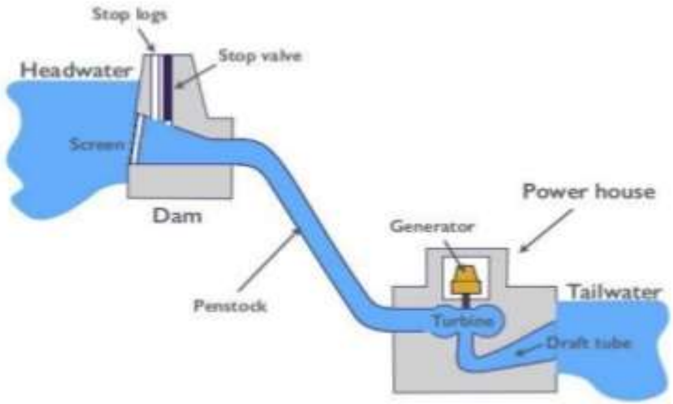
Draft Tube

The water after working on the turbine, imparts its energy to the vanes and runner, there by reducing its pressure less than that of atmospheric Pressure. As the water flows from higher pressure to lower Pressure, It can not come out of the turbine and hence a divergent tube is Connected to the end of the turbine.

Draft tube is a divergent tube one end of which is connected to the outlet Of the turbine and other end is immersed well below the tailrace (Water level).

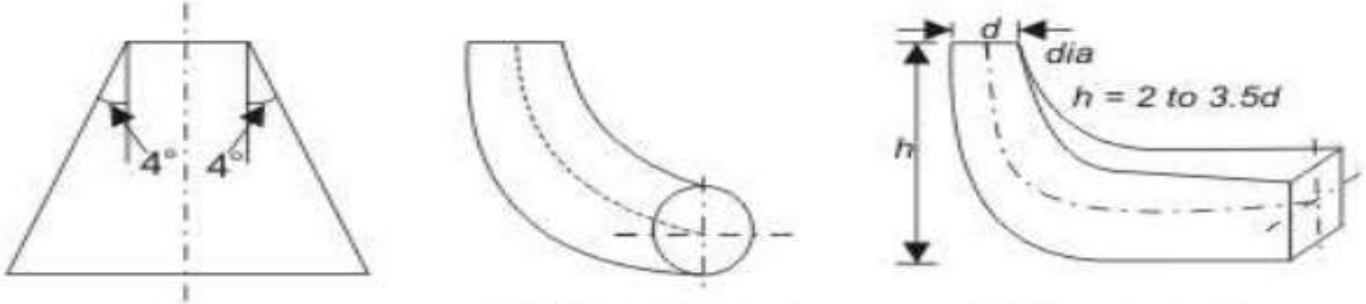
The major function of the draft tube is to increase the pressure from the inlet to outlet of the draft tube as it flows through it and hence increase it more than atmospheric pressure. The other function is to safely Discharge the water that has worked on the turbine to tailrace.

Draft Tube:-



Draft Tube

Types of Draft Tube



(a) Straight type

(b) Simple elbow type

(c) Elbow type with varying cross-section

Draft-Tube Theory. Consider a capital draft-tube as shown in Fig.

Let H_s = Vertical height of draft-tube above the tail race,

y = Distance of bottom of draft-tube from tail race.

Applying Bernoulli's equation to inlet (section 1-1) and outlet (section 2-2) of the draft-tube and taking section 2-2 as the datum line,we get

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + (H_s + y) = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + 0 + h_f$$

where h_f = loss of energy between sections 1-1 and 2-2.

But $\frac{p_2}{\rho g}$ = Atmospheric pressure head + y

$$= \frac{p_a}{\rho g} + y.$$

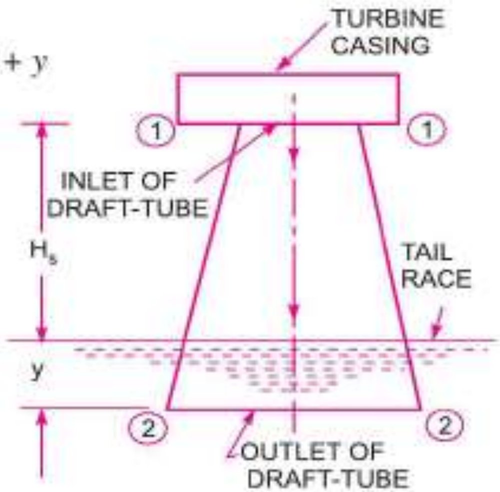


Fig. *Draft-tube theory.*

Substituting this value of $\frac{p_2}{\rho g}$ in equation (*i*), we get

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + (H_s + y) = \frac{p_a}{\rho g} + y + \frac{V_2^2}{2g} + h_f$$

or

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + H_s = \frac{p_a}{\rho g} + \frac{V_2^2}{2g} + h_f$$

$\therefore$

$$\frac{p_1}{\rho g} = \frac{p_a}{\rho g} + \frac{V_2^2}{2g} + h_f - \frac{V_1^2}{2g} - H_s$$

$$= \frac{p_a}{\rho g} - H_s - \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g} - h_f\right)$$

In equation , $\frac{p_1}{\rho g}$ is less than atmospheric pressure.

Efficiency of Draft-Tube. The efficiency of a draft-tube is defined as the ratio of actual conversion of kinetic head into pressure head in the draft-tube to the kinetic head at the inlet of the draft-tube. Mathematically, it is written as

$$\eta_d = \frac{\text{Actual conversion of kinetic head into pressure head}}{\text{Kinetic head at the inlet of draft-tube}}$$

Let V_1 = Velocity of water at inlet of draft-tube,

V_2 = Velocity of water at outlet of draft-tube, and

h_f = Loss of head in the draft-tube.

Theoretical conversion of kinetic head into pressure head in draft-tube = $\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$.

Actual conversion of kinetic head into pressure head = $\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - h_f$

$$\therefore \quad \eta_d = \frac{\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - h_f}{\left(\frac{V_1^2}{2g}\right)}$$

(Lecture 5)

Lecture contains

- Unit Quantities
- Specific Speed

Performance of Turbines under unit quantities

The unit quantities give the speed, discharge and power for a particular turbine under a head of 1m assuming the same efficiency. Unit quantities are used to predict the performance of turbine.

1. Unit speed (N_u) - Speed of the turbine, working under unit head

$$Nu = \frac{N}{\sqrt{H}}$$

2. Unit power (P_u) - Power developed by a turbine, working under a unit head

$$Qu = \frac{Q}{\sqrt{H}}$$

3. Unit discharge (Q_u) - The discharge of the turbine working under a unit head

$$Pu = \frac{P}{H^{3/2}}$$

Unit Speed, Unit discharge and Unit Power is definite characteristics of a turbine.

If for a given turbine under heads $H_1, H_2, H_3, \ldots$ the corresponding speeds are $N_1, N_2, N_3, \ldots$, the corresponding discharges are $Q_1, Q_2, Q_3, \ldots$ and the powers developed are $P_1, P_2, P_3, \ldots$. Then

Unit speed = $N_u = \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}} = \frac{N_3}{\sqrt{H_3}}$

Unit Discharge = $Q_u = \frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}} = \frac{Q_3}{\sqrt{H_3}}$

Unit Power = $P_u = \frac{P_1}{H\sqrt{H_1}} = \frac{P_2}{H\sqrt{H_2}} = \frac{P_3}{H\sqrt{H_3}}$ or $P_u = \frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}} = \frac{P_3}{H_3^{3/2}}$

Thus if speed, discharge and power developed by a turbine under a certain head are known, the corresponding quantities for any other head can be determined.

Specific Speed of Turbine

Specific Speed of a Turbine (N_s)

The specific speed of a turbine is the speed at which the turbine will run when developing unit power under a unit head. This is the type characteristics of a turbine. For a set of geometrically similar turbines the specific speed will have the same value.

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

Significance of Specific Speed. Specific speed plays an important role for selecting the type of the turbine. Also the performance of a turbine can be predicted by knowing the specific speed of the turbine. The type of turbine for different specific speed is given in Table 1 as :

Table 1

S. No.	*Specific speed*		*Types of turbine*
	(M.K.S.)	*(S.I.)*	
1.	10 to 35	8.5 to 30	Pelton wheel with single jet
2.	35 to 60	30 to 51	Pelton wheel with two or more jets
3.	60 to 300	51 to 225	Francis turbine
4.	300 to 1000	255 to 860	Kaplan or Propeller turbine

Problem *A Pelton wheel develops 8000 kW under a net head of 130 m at a speed of 200 r.p.m. Assuming the co-efficient of velocity for the nozzle 0.98, hydraulic efficiency 87%, speed ratio 0.46 and jet diameter to wheel diameter ratio* $\frac{1}{9}$, *determine :*

(i) *the discharge required,* (ii) *the diameter of the wheel,*
(iii) *the diameter and number of jets required, and* (iv) *the specific speed.*
Mechanical efficiency is 75%.

Problem *A turbine develops 9000 kW when running at 10 r.p.m. The head on the turbine is 30 m. If the head on the turbine is reduced to 18 m, determine the speed and power developed by the turbine.*

Problem *A turbine develops 500 kW power under a head of 100 metres at 200 r.p.m. What would be its normal speed and output under a head of 81 metres ?*

(Lecture 6)

Lecture contains

- Performance characteristics of Turbine

Characteristics Curves of Turbine

These are curves which are characteristic of a particular turbine which helps in studying the performance of the turbine under various conditions. These curves pertaining to any turbine are supplied by its manufacturers based on actual tests.

The characteristic curves obtained are the following:

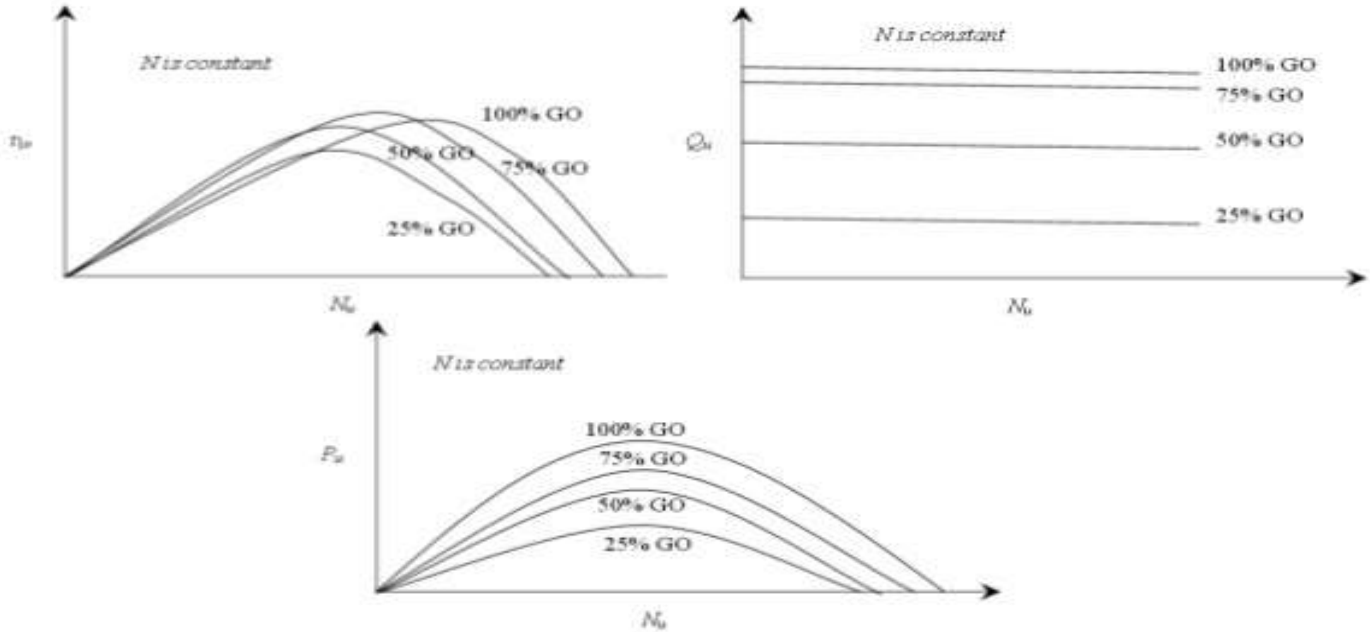
a) Constant head curves or main characteristic curves
b) Constant speed curves or operating characteristic curves
c) Constant efficiency curves or Muschel curves

Constant head curves or main characteristic curves

Constant head curves:
Maintaining a constant head, the speed of the turbine is varied by admitting different rates of flow by adjusting the percentage of gate opening. The power P developed is measured mechanically. From each test the unit power Pu, the unit speed Nu, the unit discharge Qu and the overall efficiency are determined.

The characteristic curves drawn are

a) Unit discharge vs unit speed
b) Unit power vs unit speed
c) Overall efficiency vs unit speed



Main Characteristic curves of a Pelton turbine

Constant speed curves or operating characteristic curves

Constant speed curves:

In this case tests are conducted at a constant speed varying the head H and suitably adjusting the discharge Q. The power developed P is measured mechanically. The overall efficiency is aimed at its maximum value.

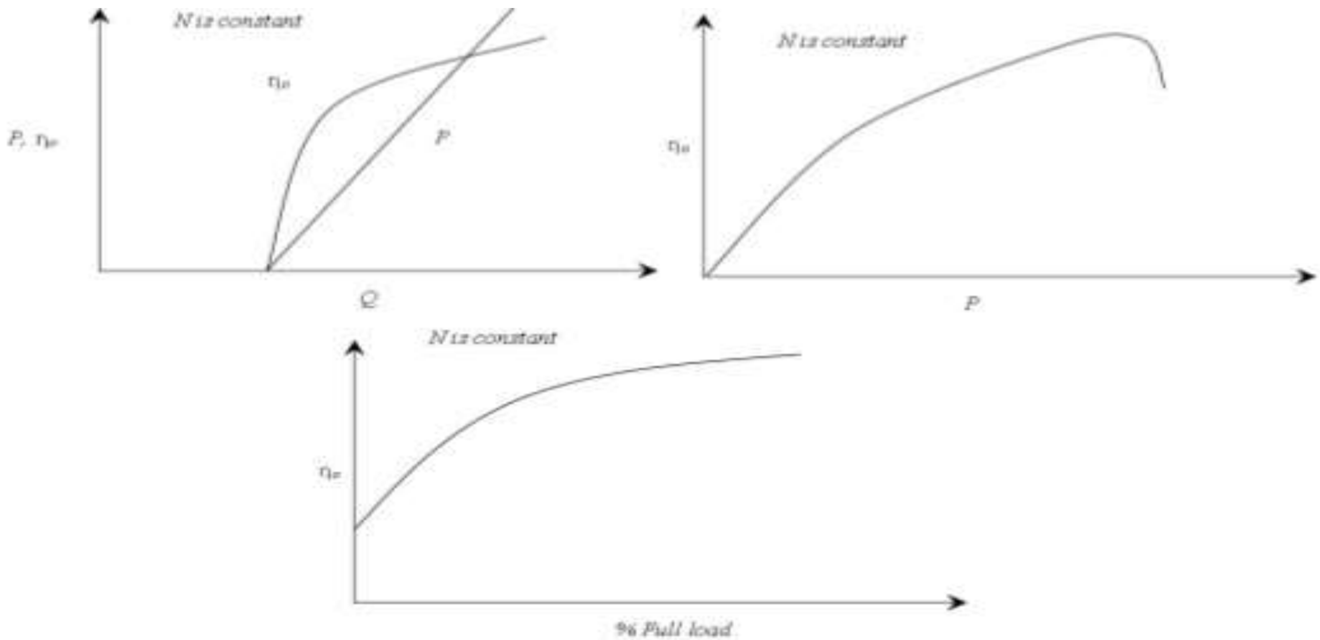
The curves drawn are

P vs Q

η_o vs Q

η_o vs P_u

$\eta_{o\,max}$ vs % Full load



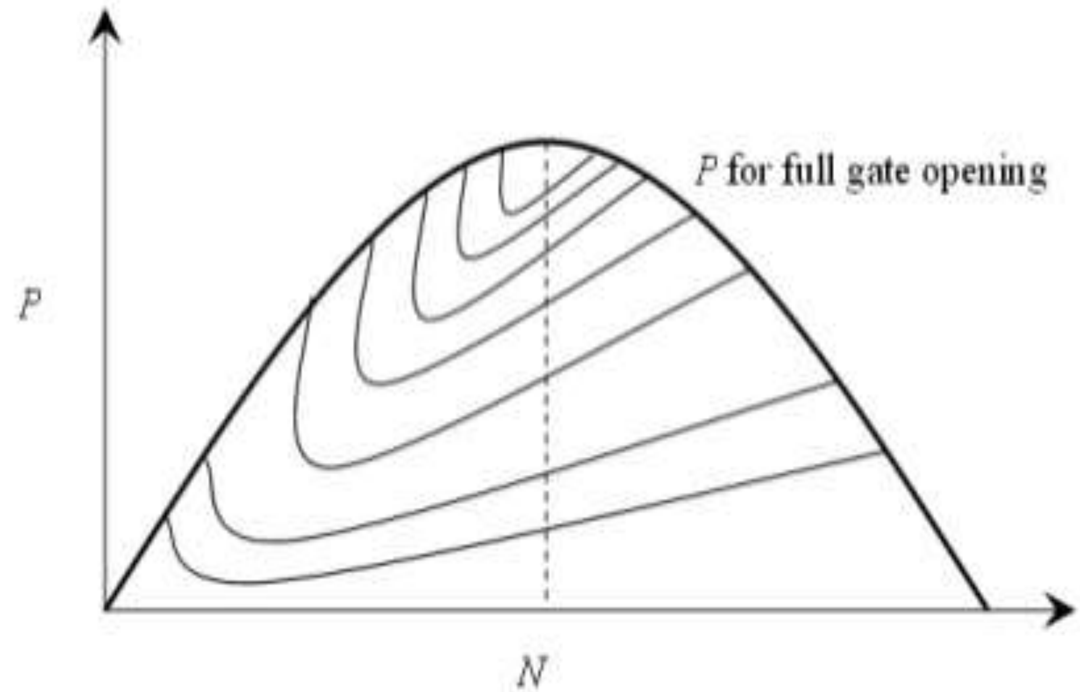
Operating Characteristic curves of a turbine

Constant efficiency curves or Muschel curves

Constant efficiency curves:

These curves are plotted from data which can be obtained from the constant head and constant speed curves. The object of obtaining this curve is to determine the zone of constant efficiency so that we can always run the turbine with maximum efficiency.

This curve also gives a good idea about the performance of the turbine at various efficiencies.



Constant Efficiency curves for Reaction turbine

(Lecture 7)

Lecture contains

- Cavitation

Cavitations

If the pressure of a liquid in course of its flow becomes equal to its vapour pressure at the existing temperature, then the liquid starts boiling and the pockets of vapour are formed which create vapour locks to the flow and the flow is stopped. The phenomenon is known as **cavitation**.

To avoid cavitation, the minimum pressure in the passage of a liquid flow, should always be more than the vapour pressure of the liquid at the working temperature. In a reaction turbine, the point of minimum pressure is usually at the outlet end of the runner blades, i.e., at the inlet to the draft tube.

Methods to avoid Cavitations

(i) Runner/turbine may be kept under water.
(ii) Cavitation free runner may be designed.
(iii) By selecting materials that can resist better the cavitation effect.
(iv) By polishing the surfaces.
(v) By selecting a runner of proper specific speed for given load.

Cavitation in Turbines. In turbines, only reaction turbines are subjected to cavitation. In reaction turbines the cavitation may occur at the outlet of the runner or at the inlet of the draft-tube where the pressure is considerably reduced (*i.e.*, which may be below the vapour pressure of the liquid flowing through the turbine). Due to cavitation, the metal of the runner vanes and draft-tube is gradually eaten away, which results in lowering the efficiency of the turbine. Hence, the cavitation in a reaction turbine can be noted by a sudden drop in efficiency. In order to determine whether cavitation will occur in any portion of a reaction turbine, the critical value of Thoma's cavitation factor (σ, sigma) is calculated.

Thoma's Cavitation Factor for Reaction Turbines. Prof. D. Thoma suggested a dimensionless number, called after his name Thoma's cavitation factor σ (sigma), which can be used for determining the region where cavitation takes place in reaction turbines. The mathematical expression for the Thoma's cavitation factor is given by

$$\sigma = \frac{H_b - H_s}{H} = \frac{(H_{atm} - H_v) - H_s}{H}$$

where H_b = Barometric pressure head in m of water,

H_{atm} = Atmospheric pressure head in m of water,

H_v = Vapour pressure head in m of water,

H_s = Suction pressure at the outlet of reaction turbine in m of water or height of turbine runner above the tail water surface,

H = Net head on the turbine in m.

(Lecture 8)

Lecture contains

- Governing of reaction turbine

GOVERNING OF TURBINES

The governing of a turbine is defined as the operation by which the speed of the turbine is kept constant under all conditions of working. It is done automatically by means of a governor, which regulates the rate of flow through the turbines according to the changing load conditions on the turbine.

Governing of a turbine is necessary as a turbine is directly coupled to an electric generator, which is required to run at constant speed under all fluctuating load conditions. The frequency of power generation by a generator of constant number of pair of poles under all varying conditions should be constant. This is only possible when the speed of the generator, under all changing load condition, is constant. The speed of the generator will be constant, when the speed of the turbine (which is coupled to the generator) is constant.

When the load on the generator decreases, the speed of the generator increases beyond the normal speed (constant speed). Then the speed of the turbine also increases beyond the normal speed. If the turbine or the generator is to run at constant (normal) speed, the rate of flow of water to the turbine should be decreased till the speed becomes normal. This process by which the speed of the turbine (and hence of generator) is kept constant under varying condition of load is called governing.

Governing of Pelton Turbine (Impulse Turbine)

Governing of Pelton turbine is done by means of oil pressure governor, which consists of the following parts :

1. Oil sump.
2. Gear pump also called oil pump, which is driven by the power obtained from turbine shaft.
3. The Servomotor also called the relay cylinder.
4. The control valve or the distribution valve or relay valve.
5. The centrifugal governor or pendulum which is driven by belt or gear from the turbine shaft.
6. Pipes connecting the oil sump with the control valve and control valve with servomotor and
7. The spear rod or needle.

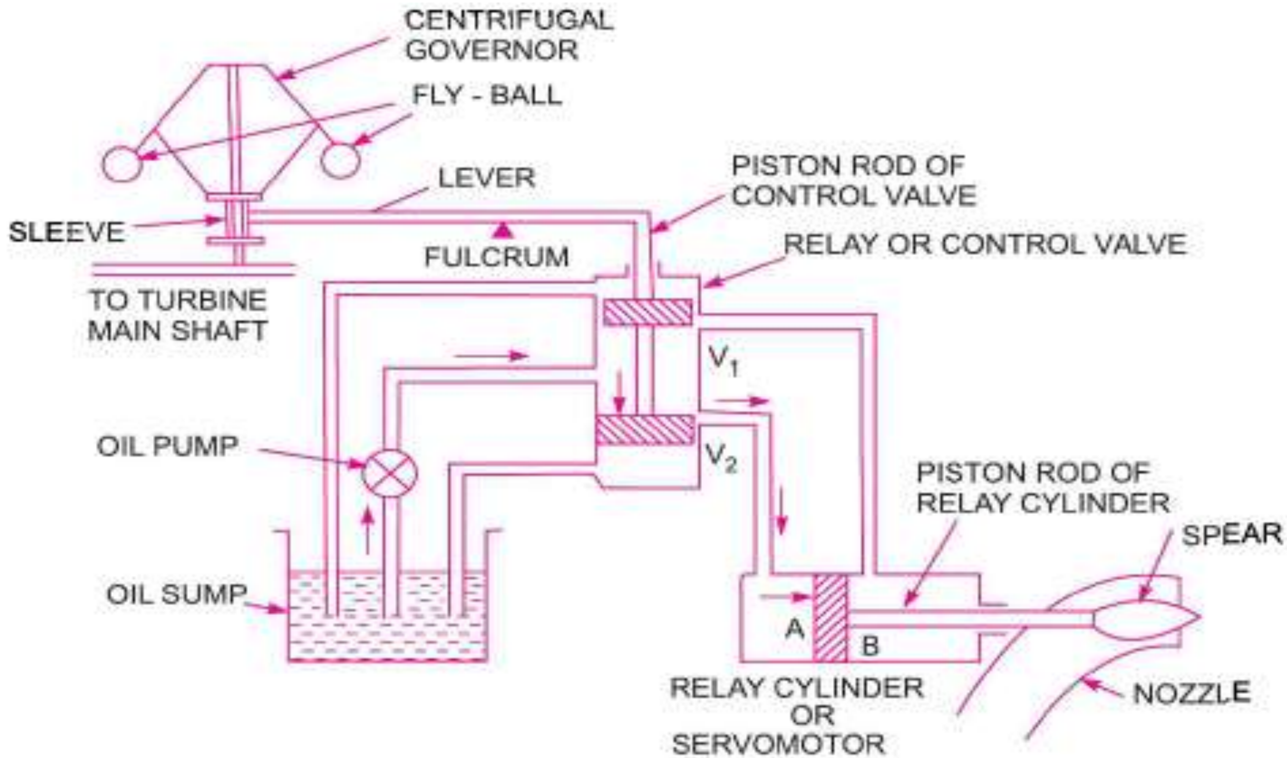


Fig. *Governing of Pelton turbine.*

When the load on the generator increases, the speed of the generator and hence of the turbine decreases. The speed of the centrifugal governor also decreases and hence centrifugal force acting on the fly-balls also reduces. This brings the fly-balls in the downward direction. Due to this, the sleeve moves downward and the lever turns about the fulcrum, moving the piston rod of the control valve in the upward direction. This closes the valve V_2 and opens the valve V_1. The oil under pressure from the control valve, will move through valve V_1 to the servomotor and will exert a force on the face B of the piston. This will move the piston along with the piston rod and spear towards left, increasing the area of flow of water at the outlet of the nozzle. This will increase the rate of flow of water to the turbine and consequently, the speed of the turbine will also increase, till the speed of the turbine becomes normal.

(Lecture 9)

Lecture contains

- Selection of water turbines

Selection of water turbines

The selection of a suitable type of turbine is usually governed by the following factors:

(i) Head and Specific Speed. It has been found that there is a range of head and specific speed for which each type of turbine is most suitable which is given in Table 2

TABLE 2

S. No.	*Head in metres*	*Type of turbine*	*Specific speed*
1.	300 or more	Pelton wheel Single or Multiple jet	8.5 to 47 (in SI units) 10 to 55 (in metric units)
2.	150 to 300	Pelton or Francis	30 to 85 (in SI units) 35 to 100 (in metric units)
3.	60 to 150	Francis or Deriaz (or Diagonal)	85 to 188 (in SI units) 100 to 220 (in metric units)
4.	Less than 60	Kaplan or Propeller or Deriaz or Tubular	188 to 860 (in SI units) 220 to 1000 (in metric units)

However, as a general rule, it may be stated that as far as possible a turbine with highest permissible specific speed should be chosen, which will not only be the cheapest in itself but its relatively small size and high rotational speed will reduce the size of the generator as well as the power house. But the specific speed cannot be increased indefinitely, because higher specific speed turbine is generally more liable to cavitation. The cavitation may, however, be avoided by installing the turbine at a lower level with respect to the tail race.

Selection of water turbines

(ii) **Part Load Operation.** The turbines may be required to work with considerable load variations. As the load deviates from the normal working load, the efficiency would also vary. In Fig. 22.5 a plot between η_0 and % of full load has been shown. At part load the performance of Kaplan and Pelton turbines is better in comparison to that of Francis and Propeller turbines. The variability of load will influence the choice of type of turbine if the head lies between 150 m to 300 m or lies below 30 m. For higher range of heads Pelton wheel is preferable for part load operation in comparison to Francis turbine, though the former involves higher initial cost. For heads below 30 m, Kaplan turbine is preferable for part load operation in comparison to Propeller turbine.

In addition to above mentioned factors there are certain other factors to be considered for the selection of the suitable type of a turbine. The *overall cost* which includes the initial cost and the running cost should be considered. The *cavitation* characteristics of the turbine should also be considered since it affects the installation of a reaction turbine.