Electrical Power Generation & Economics– BEE405A
Module-1 Hydro Power Plants

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Course Outline

Module-1 - **Hydroelectric Power Plants**

- Hydrology, run off and stream flow, hydrograph, flow duration curve,
- Mass curve, reservoir capacity, dam storage. Hydrological cycle, merits and demerits of hydroelectric
- power plants, Selection of site. General arrangement of hydel plant, elements of the plant,
- Classification of the plants based on water flow regulation, water head and type of load the plant has to supply.
- Water turbines – Pelton wheel, Francis, Kaplan and propeller turbines. Characteristic of water turbines Governing of turbines, selection of water turbines.
- Underground, small hydro and pumped storage plants. Choice of size and number of units, plant layout and auxiliaries

Selection of site

- Availability of water
- Storage of water
- Head of the water
- Cost and type of land
- Transportation facilities
- Distance of power station site from load centers

Merits and demerits of hydroelectric power plant

- **Merits:**

1. Operation, running and maintenance costs are low.
2. Once the dam is built, the energy is virtually free.
3. No fuel is burnt and the plant is quite neat & clean.
4. No waste or pollution produced.
5. Generating plants have a long lifetime.
6. Hydroelectric turbine-generators can be started and put "on-line" very rapidly.
7. Electricity can be generated constantly.

Merits and demerits of hydroelectric power plant

- **Demerits:**
- Very much land-use oriented and may flood, large regions.
- The dams are very expensive to build .
- Capital cost of generators, civil engineering works and cost of transmission lines is very high.
- Finding a suitable site can be difficult

IMPORTANT TERMINOLOGY

- **Hydrology:** Hydrology can be defined as a part of science that deal with the study of the properties, distribution, quality and effects on water resources over and within the surface of the earth.
- **Hydrological water cycle:** The cyclic movement of water is called the hydrological cycle.
- **Run off and Stream flow:** the flow of water in streams, rivers and other channels

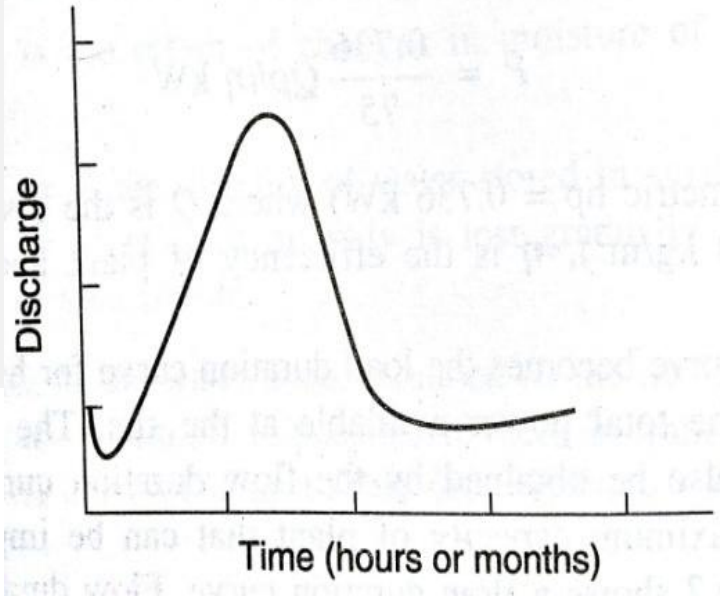
Elements of water cycle are:

- Precipitation
- Evaporation
- Infiltration
- Transpiration

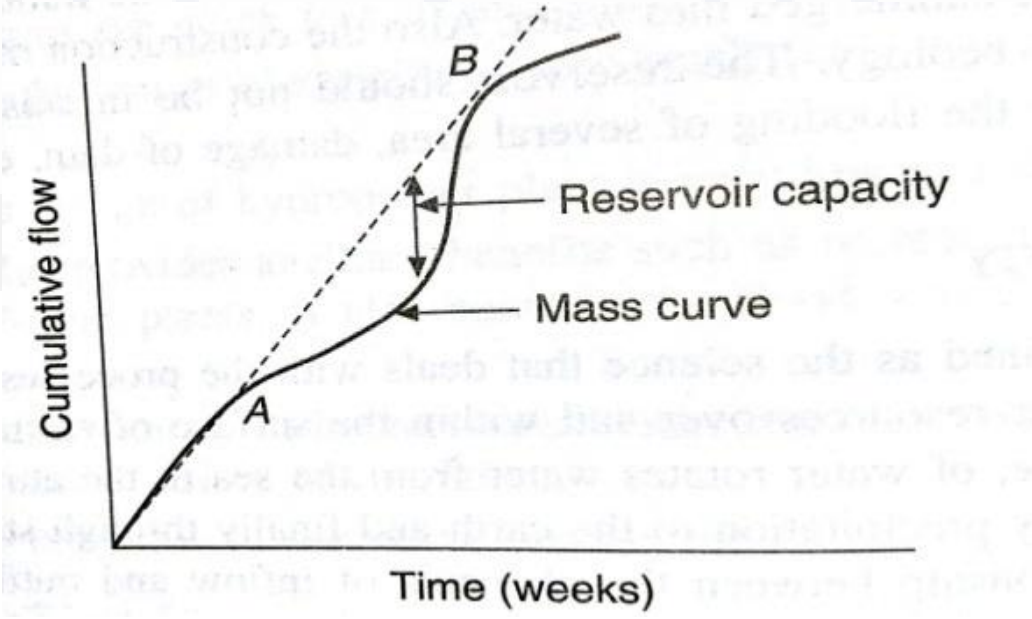
Run off = Precipitation - Evaporation

IMPORTANT TERMINOLOGY

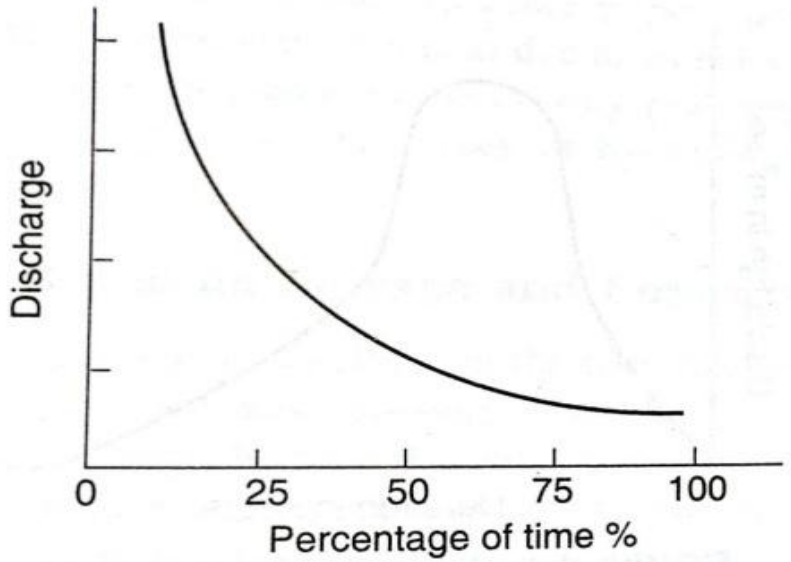
- **Hydrograph:** A graphical representation of water flow discharge with respect to time.



- **Mass curve:**
- Mass curve is a plot of cumulative volume of water that can be stored from stream flow verses time in days, months or years.
- Maximum intercept between line AB and mass curve is known as reservoir capacity.



- **Flow Duration curve:**
- It is plot of discharge verses % time for which the discharge is available. It is obtained from hydrograph data.



- The flow duration curve becomes the load duration curve for the hydroelectric plant

- **Reservoir capacity:** It is a capacity of a reservoir to store water. Storage can be Natural or artificial storage.
- Based on storage the power generation capacity can be decided.

Sl.No.	Type of Plant capacity	Capacity in MW
1	very low	up to 0.1
2	Low	up to 1
3	Medium	up to 10
4	High	> 10

Sl.No.	Hydro Plant	Capacity
1	Micro	<100 KW
2	Mini	100KW - 1 MW
3	Small	1MW - few MW
4	Hydro	few MW - 1000MW
5	Super Hydro	> 1000MW

IMPORTANT TERMINOLOGY

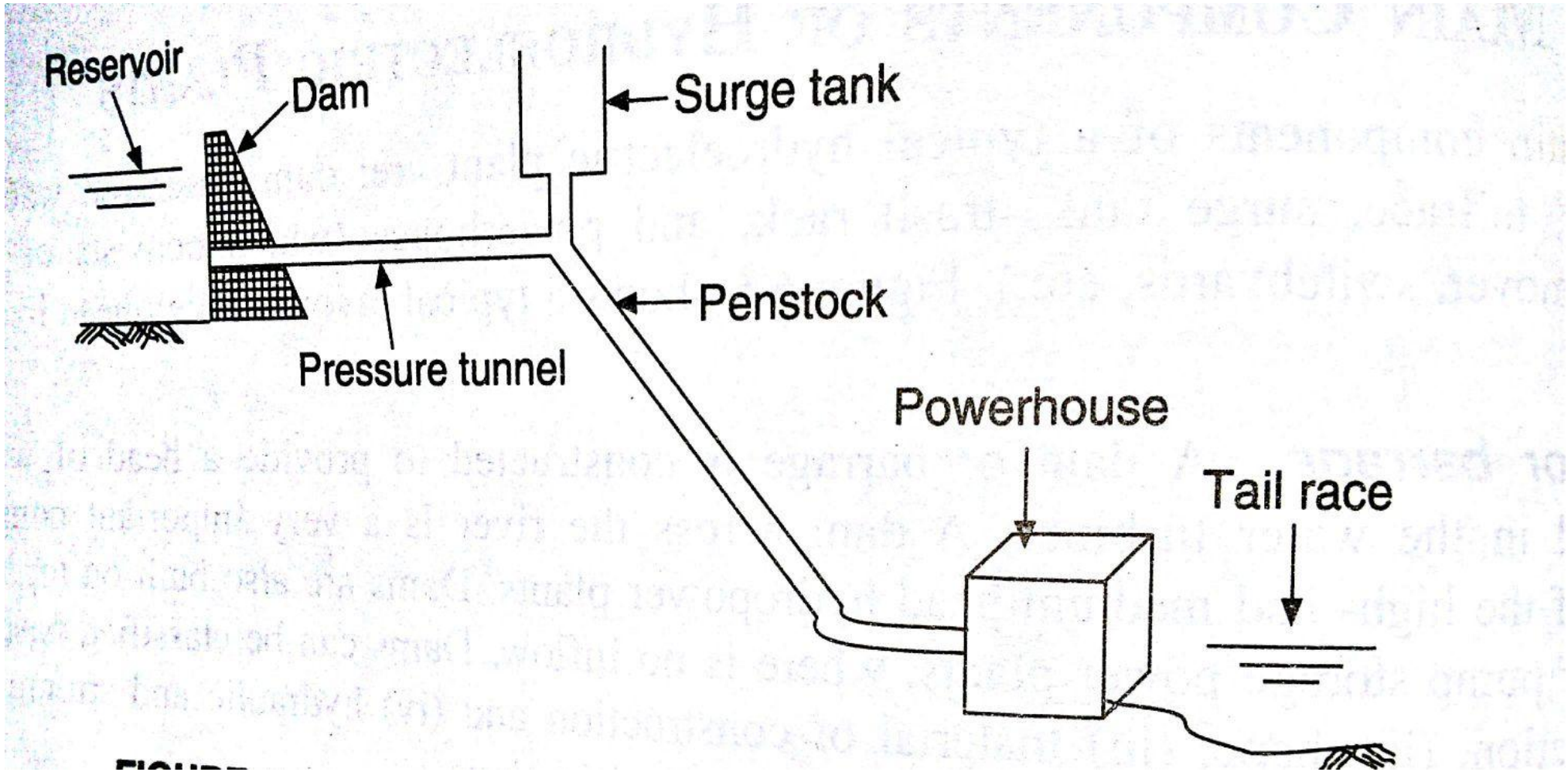
Dam storage:

- Dam built to catch surface runoff and stream water flow in order to regulate the water flow, Storage dams are used to store water for extended lengths of time.
- The stored water then can be used for irrigation, livestock, municipal water supply, recreation, and hydroelectric power generation.

Main Elements of the Hydro Power Plant

- **Reservoir :** It is a basic requirement of a hydroelectric plant to store water which may be utilized to produce electric power when required. It stores water during rainy season and supply the same during dry season.
- **Forebay:** It is used for storing water temporarily. Based on the loading condition water flow will be increased or decreased to meet the demand.

General arrangement of hydel plant



Main Elements of the Hydro Power Plant

- **Dam:** Dam provides the necessary head of water to be utilized in the water turbine. it also increases the reservoir capacity.
- **Trash Rack:** It prevents the entry of debris to the turbine nozzles and gates. It is made up of steel and placed across the intake.
- **Surge Tank:** It is the additional storage near the turbine. It is used to provide necessary head and prevents the rapid change in flow of waters. Surge tank is provided at the intake of the penstock.

Main Elements of the Hydro Power Plant

- **Penstock:** It is a conduit which carries water from reservoir/forebays/surge tank to the turbine.
- **Spill way:** It is said as a safety valve for the dam. It discharges the excess water in the reservoir which over the permissible level.
- **Power House:** power house is usually located at the foot of the dam or at the storage reservoir. It consists of hydraulic and electrical equipments
- **Prime Mover:** prime mover is used to convert kinetic energy of water to mechanical energy. Commonly used turbines are Pelton wheel, Francis, Kaplan and Propeller turbines.
- **Tailrace:** it is required to discharge the water leaving turbine, into the river.

Classification of Hydroelectric power plant

They are classified in three different methods

- Quantity of water available
- Available Head
- Nature of Load

Quantity of water available

- **Run-off river plants with out pondage** : These plants does not store water, the plant uses water as it comes.
- The plant can use water as and when available.
- These plants depend for their generating capacity primarily on the rate of flow of water.
- **Run-off river plants with pondage :** In these plants pondage permits storage of water during off peak periods and use of this water during peak periods.

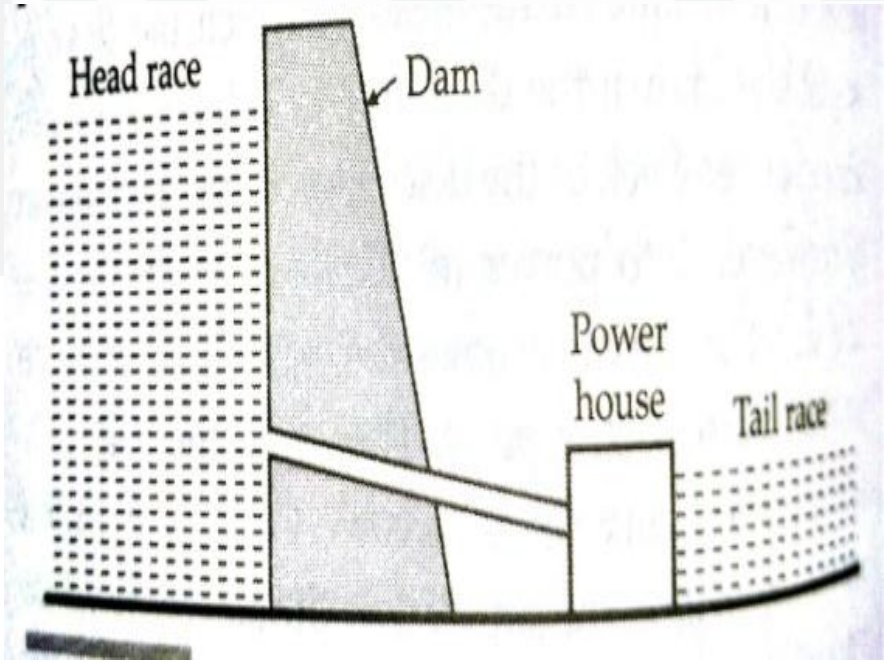
Quantity of water available

Reservoir Plants :

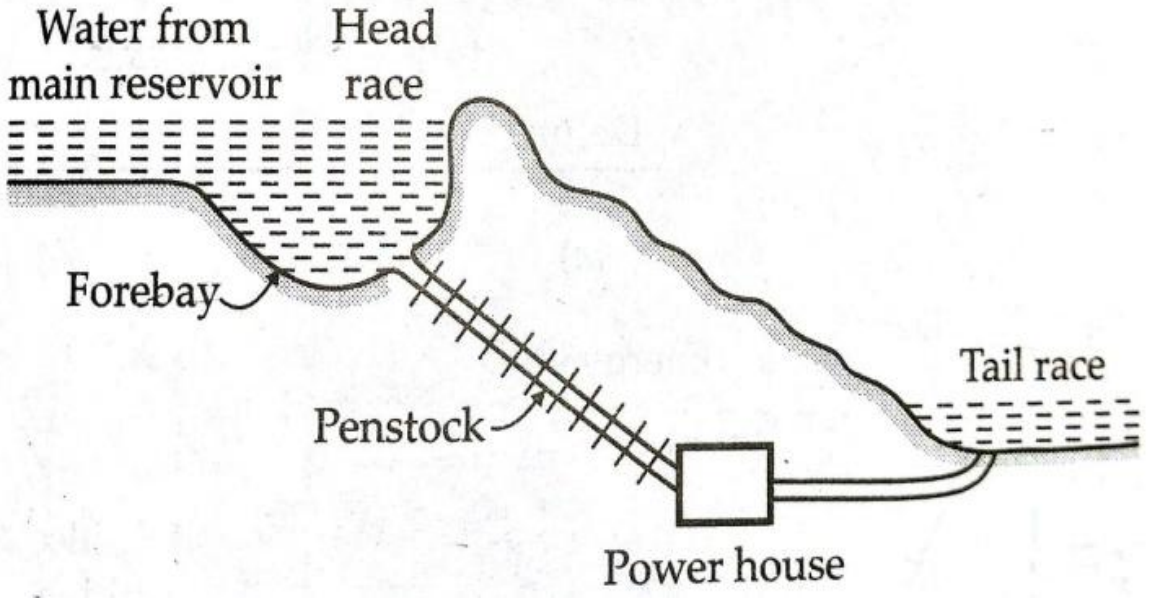
- A plant which has a reservoir to permit carrying over storage from wet season to the next dry season.
- Water is stored behind the dam and is available to the plant with control as required.

Available Head

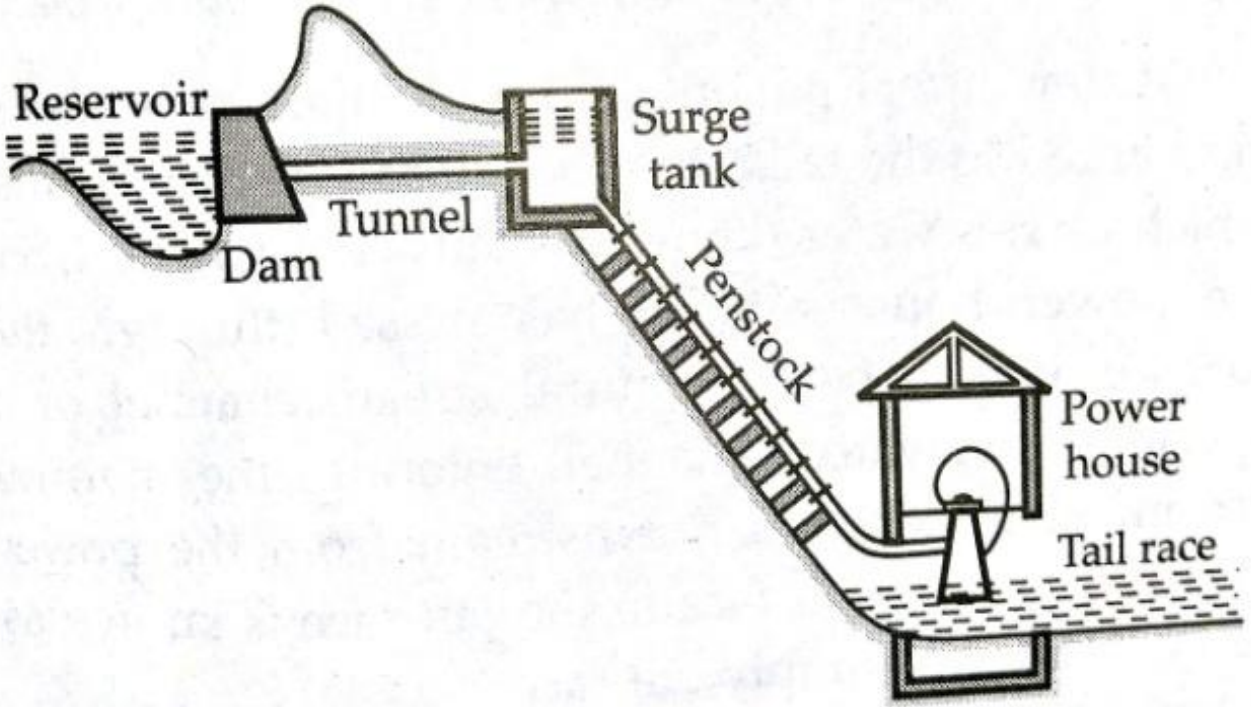
- **Low-Head (less than 30 meters) Hydro electric plants :**"Low head" hydro-electric plants are power plants which generally utilize heads of only a few meters or less and simply use the "run of the river".



- **Medium-head(30 meters - 300 meters) hydro electric plants :**These plants consist of a large dam which creates a huge reservoir.
- No surge tank required, forebay acts as a surge tank.
- For each Penstock, turbines are connected and usually Kaplan, Francis and propeller types of turbine are used.



- **High-head hydroelectric plants >300meters** :"High head" power plants are the most common and generally utilize a dam to store water at an increased elevation.
- The Dam provides the capability of storing water during rainy periods and releasing it during dry periods
- It has consistent and reliable production of electricity.



Classification According to load

- Base load plant
- Peak load plants
- Pumped storage plants

1. **Base load plant:**

- Run-off river plants without pondage and reservoir plants are used as base load plants.
- These feed the base load of the system.
- they supply almost constant load throughout and operate on at high load factor

Classification According to load

Peak load plants: These are meant to supply the peak load of the system. Run off river plants with pondage and Reservoir plants can be used as peak load plants during lean flow period.

- Peak load plant have large seasonal storage. They store water during off-peak periods and run during peak load periods.

Pumped storage plants: it is a special type of plant meant to supply peak loads.

- During peak load period, water is drawn from the head water pond through the penstock and generates power for supplying the peak load.
- During the off-peak period, same water is pumped back from tail race water pond to head water pond to use the same water again to generate the power.

Selection Of Water Turbine

- **Head of water**

TYPE OF TURBINE	HEAD	SPECIFIC SPEED (metric units)
Pelton	>200m	Upto 50
Francis	30m-200m	60-300
Propeller	<30m	300-1000

- **Specific Speed:** High speed is required where head is low and output is large, on the other hand with greater head low speed is sufficient. Even with low specific speed greater rotational speed can be obtained which can be used in medium capacity plants.
- **Rotational speed:** It is directly proportional to a specific speed. It depends on frequency and number of poles. The specific speed selected must be in a way that it will give the synchronous speed of the generator.
- **Efficiency:** The turbine selected must give the highest overall efficiency for various operating conditions.

Selection Of Water Turbine

- **Part load operation:** Even at part load and full load it should operate at its maximum efficiency. So that it can be very economical.
- **Disposition of turbine shaft:** Vertical shaft arrangement is better for reaction type turbine and horizontal arrangement is better for the impulse type turbine**.**

Difference between Impulse & Reaction Turbine

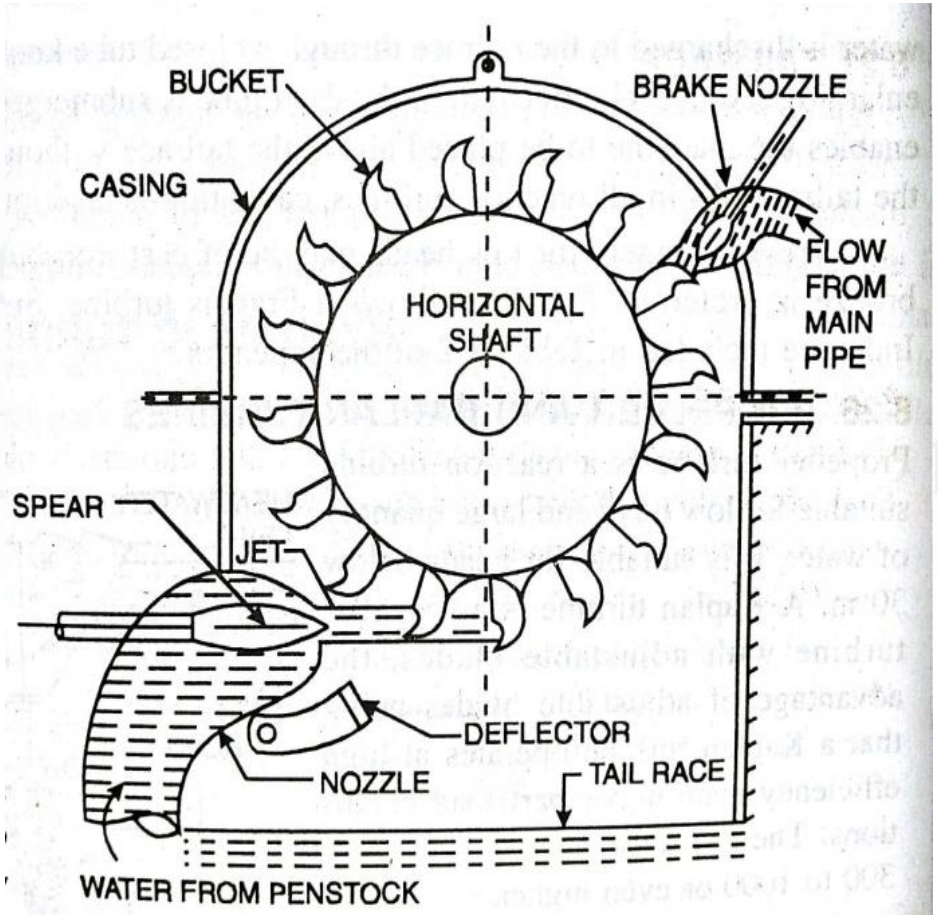
Impulse Turbine	Reaction Turbine
blades are symmetrical	blades are not symmetrical
Impulse Turbine occupies less space per unit power	Reaction Turbine occupies more space per unit power.
Pressure remains constant during it's flow through moving blade	pressure is reduced during it's flow through moving blade.
Impulse Turbine is used for small power requirement	Reaction Turbine is used for high power requirement.
Pelton Wheel	Francis **turbine,** propeller **turbine**

Characteristics Of Turbines

- **Head:** based on head turbines are used upto 200m reaction turbine and > 200m impulse turbine is used.
- **Efficiency at various load:** impulse turbine as a efficiency of 80-85%, reaction turbine has efficiency or 85-95%. Where in kaplan turbine has a greater efficiency at lighter load also.
- **Specific speed (n_s) :** it is defined as a speed at which turbine runs to develon_sp 1 metric HP under head of 1 meter.
- $= nP^{1/2}/h^{5/4}$ rpm
- **n = Rotor Speed**
- **P= Power in kW**
- **Runaway speed:** it is a maximum speed at which turbine runs under the worst condition of operation with all gates open, maximum head. The generator coupled must be able to with stand the speed of the turbine.

Types of Water Turbine

- **Pelton Wheel**

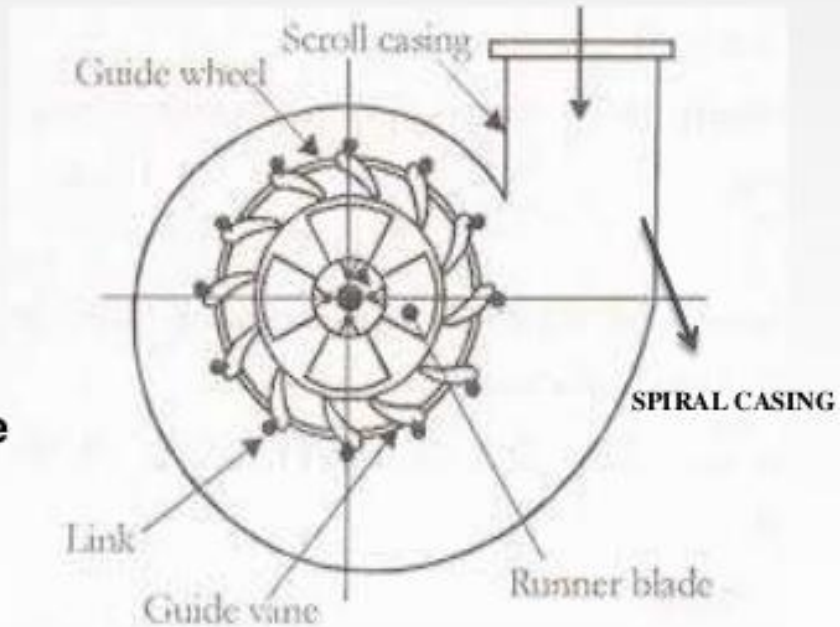


Types of Water Turbine

- **Pelton Wheel**
- The potential energy of water is converted to a kinetic energy in a jet of water coming out from nozzle.
- This water jet will hit the buckets which is fixed on the rotor periphery and cause the motion of the rotor. After performing work, water is discharged into tailrace.
- Each buckets are divided into two hemispherical cups and which is rigid at the center.
- The rate of water flow is controlled by the spear.
- Each turbine can have 1- 4 jets.
- Buckets is made up of cast iron, bronze, steel. Rotor is made up of cast steel. Buckets are welded or bolted to the rotor.

Components of Francis turbine:

- Penstock
- Spiral casing
- Guide vanes/ Stay vanes
- Runner and Runner blade
- Draft tube



Types of Water Turbine

- **Francis Turbine**
- It is a reaction turbine with medium head and medium flow.
- It is built in large size and generally with vertical configuration.
- The turbine develops power due to the velocity of water and the difference in pressure between the front and back of the runner buckets.
- The water, under pressure will enter the runner from the guide vanes radially and will discharge axially.
- The pressure is at the inlet is more than the outlet, the water flows through the closed loop hence water is present in runner always.

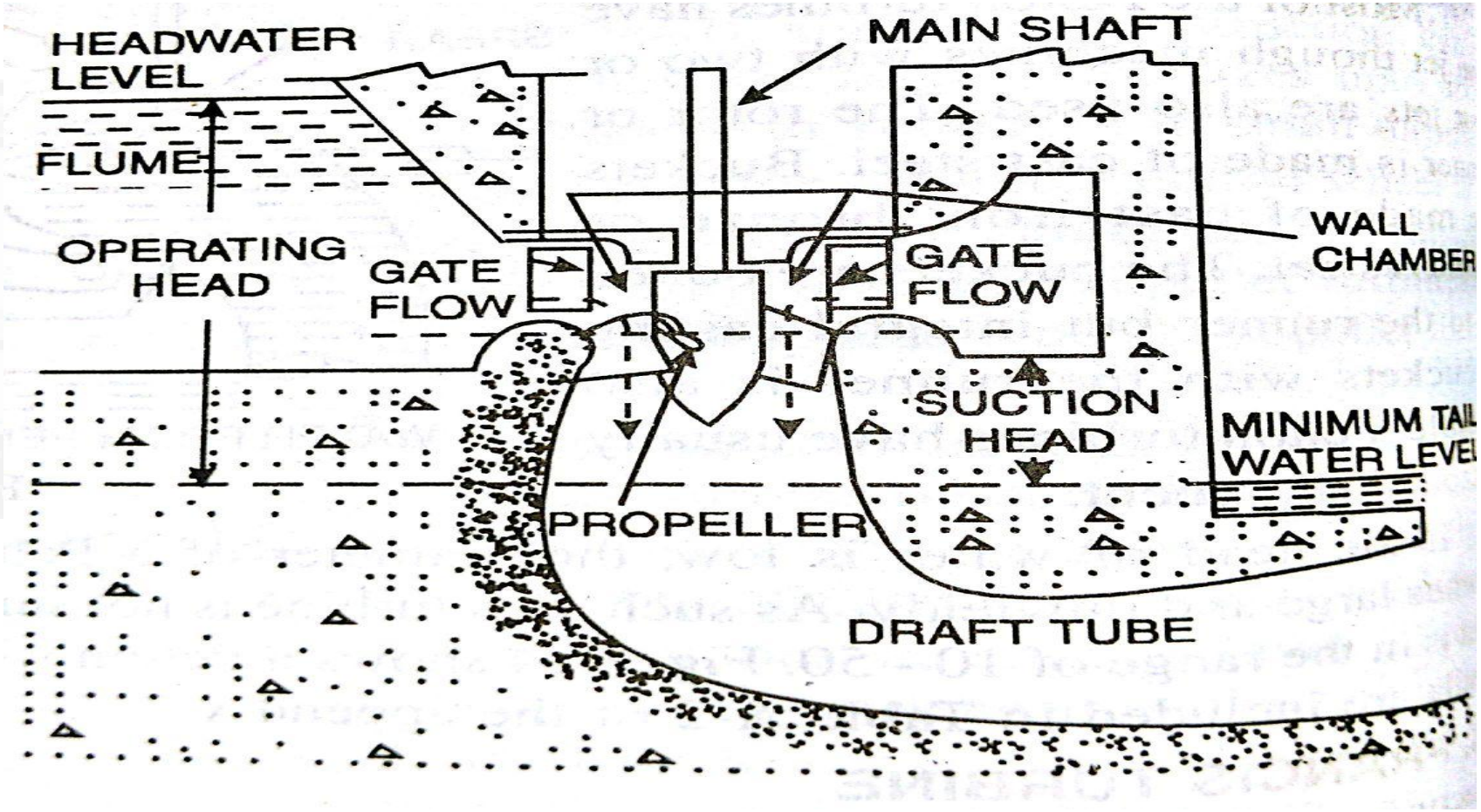
Types of Water Turbine

Francis Turbine

- It is made up of cast iron, bronze or steel
- It is used for the head being 30m-200m with speed 60-300 metric units
- motion of water is controlled by wicket gate, fixed around the runner. The water will pass through a spiral case of a runner.

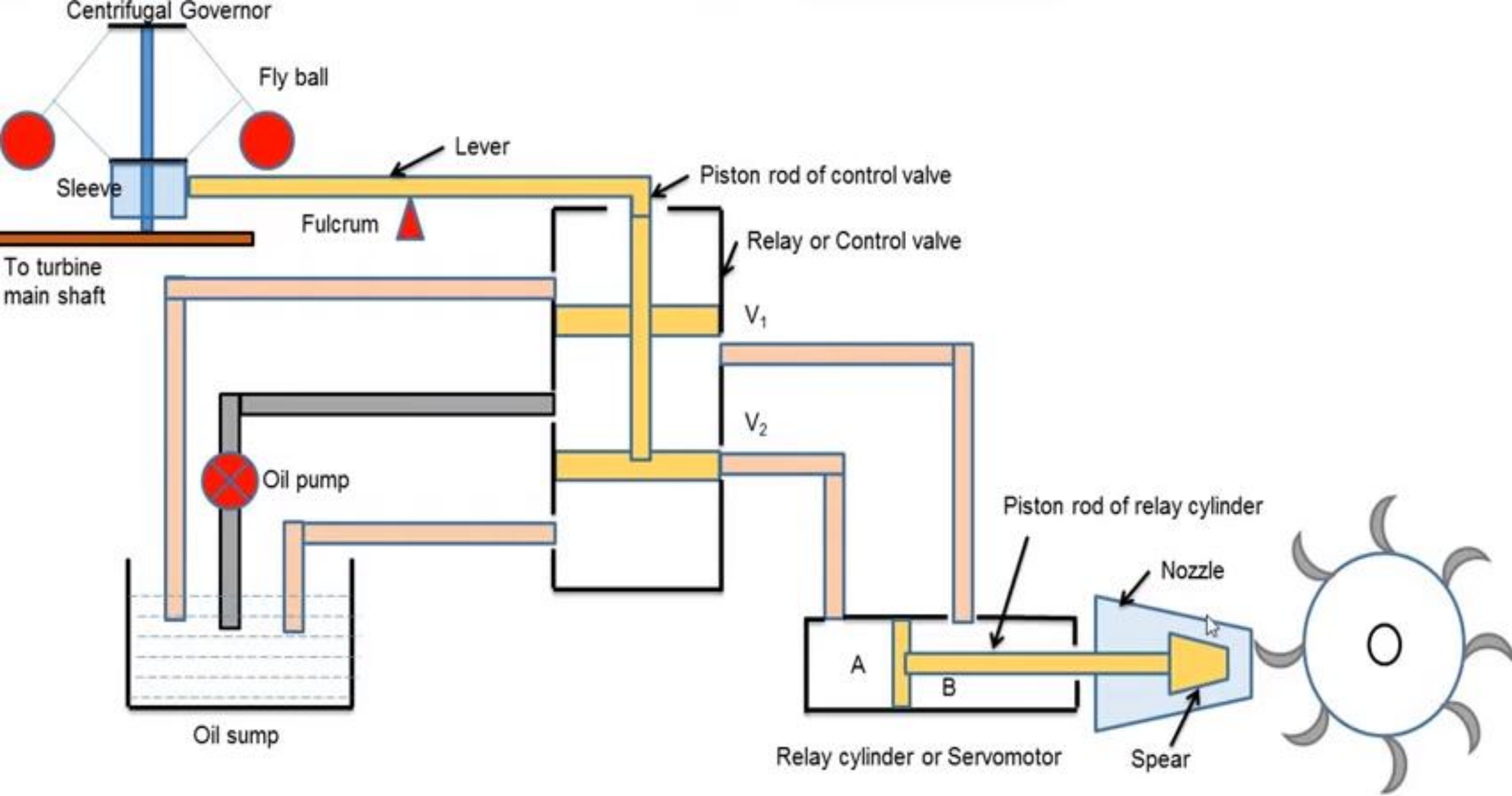
Types of Water Turbine

- **Kaplan Turbine**



Types of Water Turbine

- **Kaplan Turbine**
- It is a reaction turbine with low head and large quantity of water.
- Kaplan turbine is a propeller turbine with adjustable blades.
- Kaplan turbine has higher efficiency at lighter load
- Spiral casing, guide mechanism is same as francis turbine.
- It is used for the head being <30m with weight of 300-1000metric tones.
- speed ranges from 400-1500rpm, results in lower cost runner and alternator with cheaper power house structure.


Centrifugal Governor
Fly ball
Lever
Sleeve
Piston rod of control valve
Fulcrum
Relay or Control valve
To turbine
main shaft
V_1
V_2
Oil pump
Piston rod of relay cylinder
Nozzle
A
B
Oil sump
Relay cylinder or Servomotor
Spear

Governing of Turbine

1.Oil Pump & oil sump :-The system requires an oil sump to store the oil and an oil pump to regulate the oil supply in the mechanism.

2.Relay or control valve:-Relay valve is a spool valve having 5 ports, it receives the pressurized oil from the oil pump which is diverted towards the servomotor cylinder and return back to the sump.

3.Servomotor or relay cylinder :-It is double acting cylinder which acts as hydraulic actuator. It forces the received oil into the oil sump with the help of displaced piston.

4.Governor & Linkages :-A centrifugal governor is used as the measuring element of the closed loop control system. It is driven by the turbine shaft. The sleeve of the governor is connected through linkages to relay valve. The movement of sleeve is transferred through the lever.

5.Regulating Ring :-It is a circular ring having guide vanes pivoted at a point through the levers and links.

6.Regulating rod :-It connects the regulating ring to servomotor.

THANK YOU