EEE 411
Power Station Engineering

HYDRO ELECTRIC POWER PLANT

Introduction

- Generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as a **hydro-electric power station.**

- For generating electricity, two types of energy are used from water :

  1. Kinetic Energy

  2. Potential Energy

Energy

- **Kinetic Energy:** When the water is in motion, this kinetic energy is used. For example, using the wave of seawater.
- **Potential Energy:** Creating height difference from earth level, produces potential energy in water.

- **Energy = water mass * g * height(or head)= mgh**

Classification

Based On generation , it can be divided by five types:

1. **Micro Hydro Power Plant** : Generation <100KW
2. **Mini Hydro Power Plant** : Generation 100KW to 1MW
3. **Small Hydro Power Plant** : Generation 1MW to few MW (few can be 10 or not fixed)
4. **Hydro Power Plant** : Generation more than few MW
5. **Super Hydro Power Plant** : Generation more than 1000MW

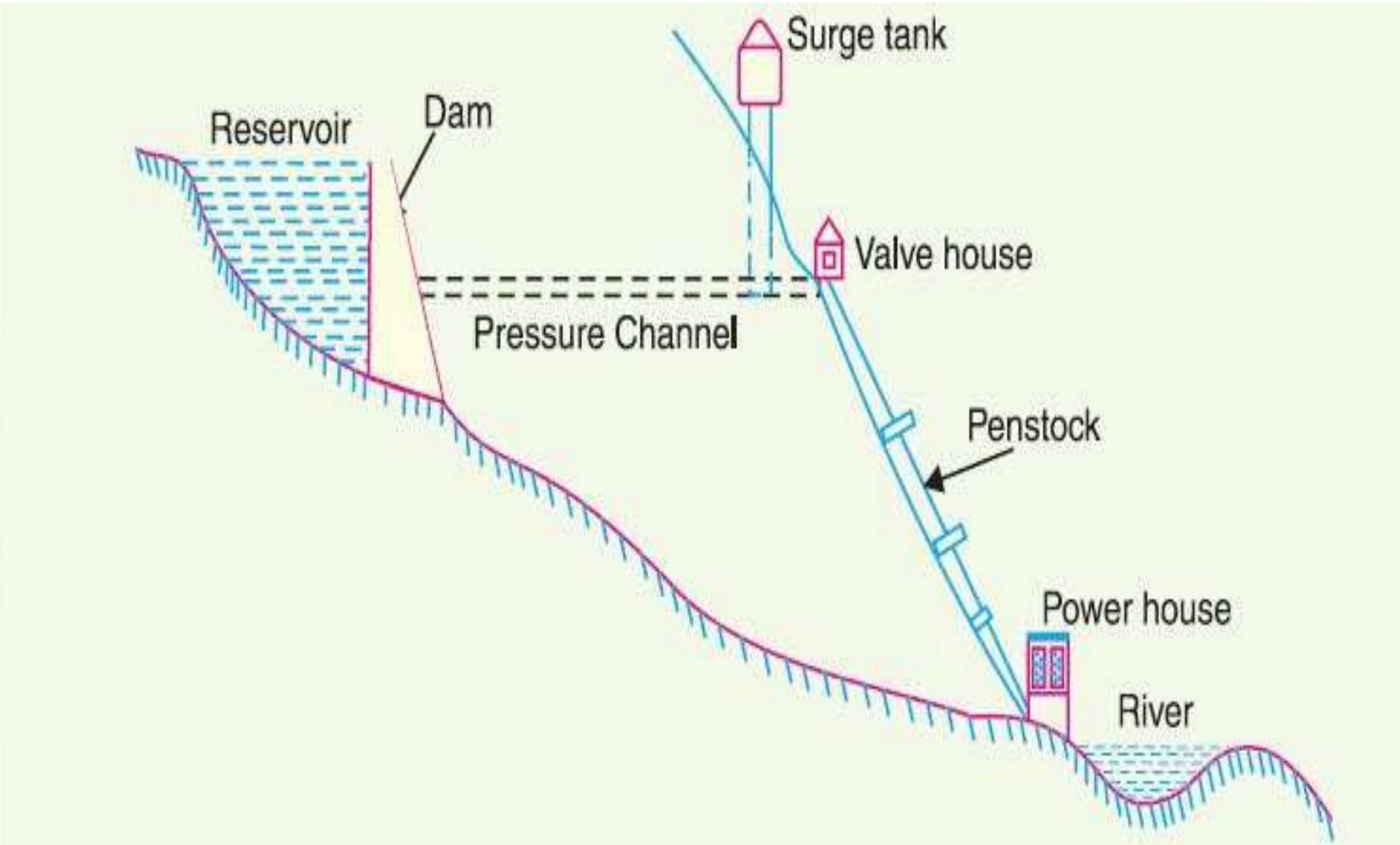
Classification (contd.)

Based on Head, It can be divided by 4 types

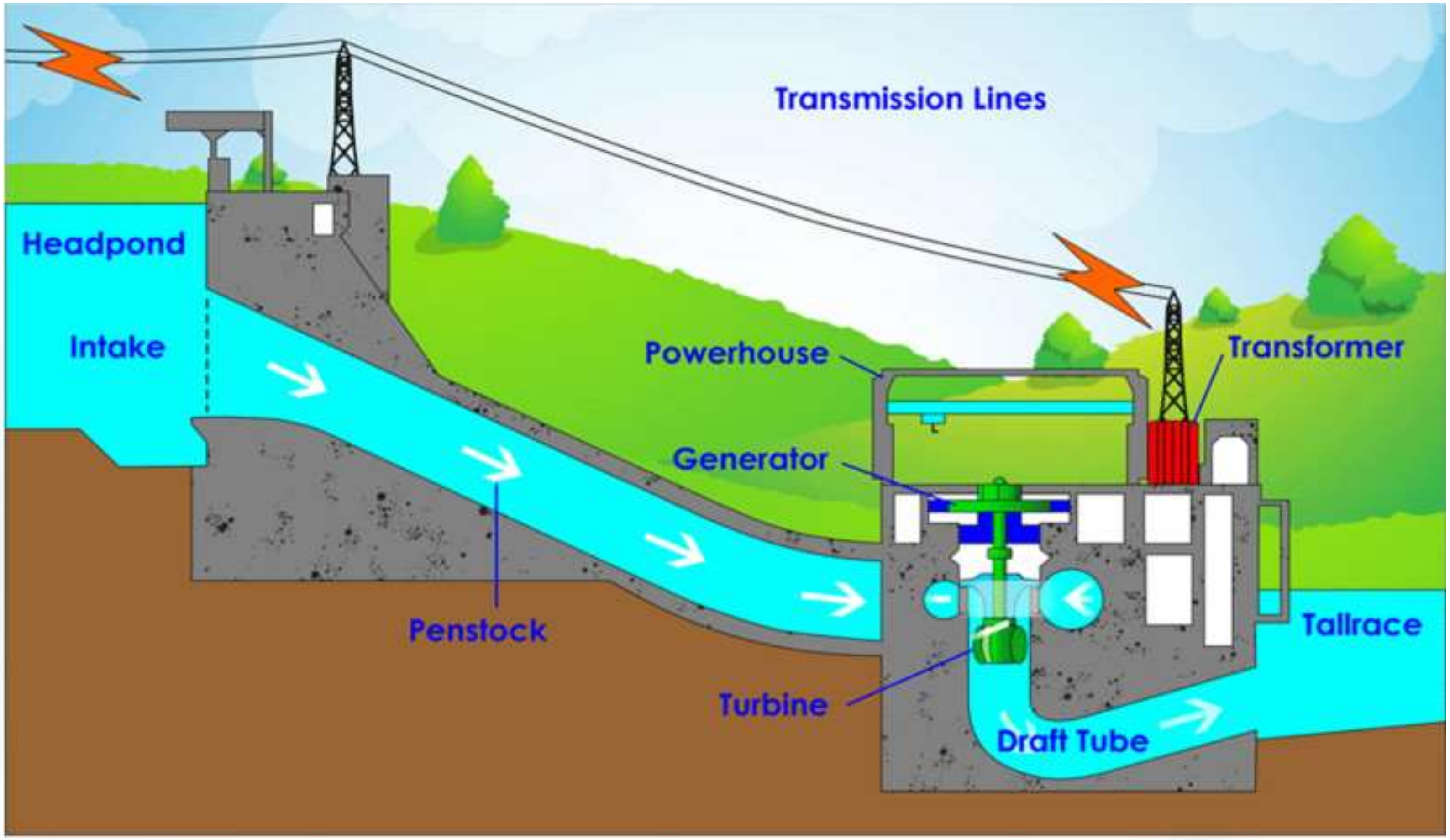
1. **Low head :** head < 15m
2. **Medium head :** head is 15~70m
3. **High head :** head is 71~250m
4. **Very High head :** head is greater than 250m

High head needs less amount of water
whereas low head needs much water

Schematic Arrangement of Hydro-electric Power Station



Hydro Power Plant (contd.)



Operations

- **Dam** is constructed across a river or lake and water from the catchment area collects at the back of the dam to form a **reservoir.**

- **pressure tunnel** is taken off from the reservoir and water brought to the start of the **penstock.**

- water is taken to water turbine through a huge steel pipe known as ***penstock.***

- **water turbine** converts hydraulic energy into mechanical energy

- **turbine** drives the **alternator** which converts mechanical energy into electrical energy.

- A **surge tank** protects the **penstock** from bursting in case the turbine gates suddenly close due to electrical load being thrown off.

Main Components

1. Hydraulic Structures:

i. Dams or Barriers:

-barrier which stores water and creates water head.

-built of concrete or stone masonry, earth or rock fill.

- 50~100m dams are created by earth but high head dams created by RCC.

- type of dam depends upon the foundation conditions, local materials and transportation available, occurrence of earthquakes and other hazards.

Main Components

1. Hydraulic Structures:

ii. Spillways:

-gives protection from the water overflow

-Such a situation arises during heavy rainfall in the catchment area

-discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam

iii. Reservoir:

-stores water if the water availability is uneven

iv. Tailrace:

-After passing through the turbine, water is discharged to river or other place through it.

Main Components

1.Hydraulic Structures:

v. HeadWorks:

-consists of the diversion structures at the head of an intake.

-include booms and racks for diverting floating debris, sluices for by-passing debris and sediments and valves for controlling the flow of water to the turbine.

vi. Pressure Channel:

-Carries water from reservoir to the beginning of penstock.

vii. Penstocks:

-carries water to the turbines.

-made of reinforced concrete or steel.

-thickness of the penstock increases with the head or working pressure.

Main Components

1.Hydraulic Structures:

vii. Surge Tank:

- a small reservoir or tank used to limit the abnormal pressure in the penstock.
- water level rises or falls to reduce the pressure swings in the penstocks
- located near the beginning of the conduit

- **At a steady load** , the quantity of water flowing in the conduit is just sufficient to meet the turbine requirements.

- **At low demand** , the gate of the turbine closes, reducing the water supply to the turbine.

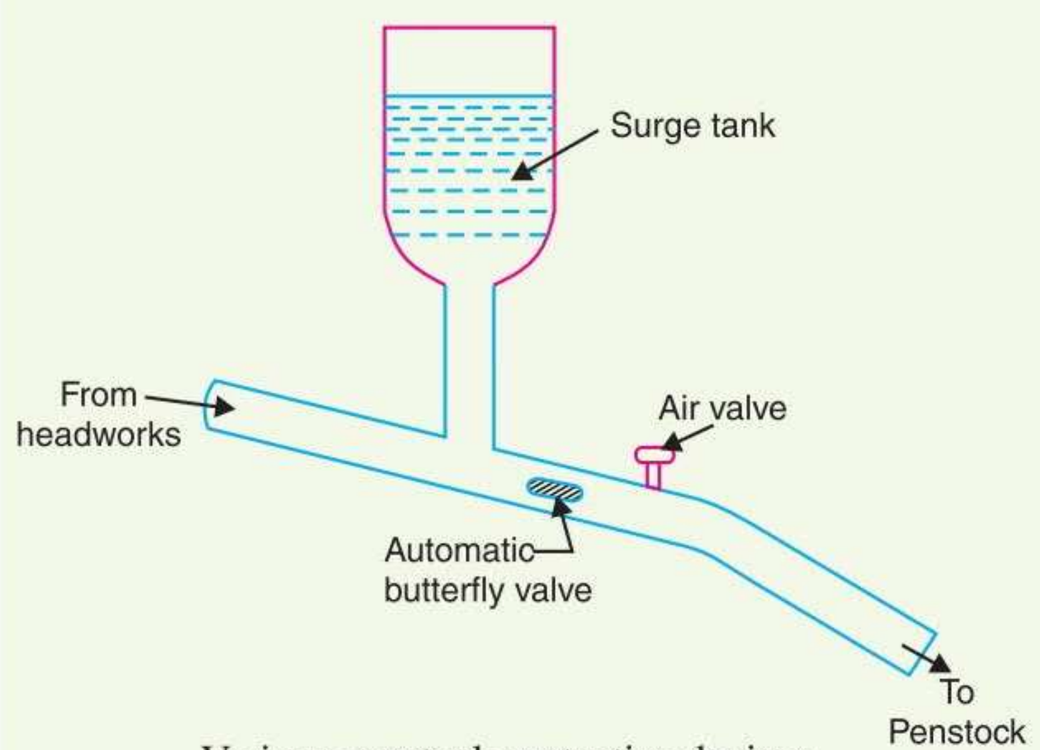
- excess water rushes back to the surge tank and reducing the pressure on the penstocks.

- **At high demand** , water is drawn from the surge tank to meet the increased load requirement

- Thus, it helps to prevent **water hammering.**

Water hammering is a pressure surge when water is forced to stop or change direction suddenly.

Without this, the penstocks may burst due to the huge pressure of water.



Various penstock protective devices

Main Components

2.Water Turbines:

Pelton turbine   Francis turbine

Kaplan Turbine

Main Components

2. Water Turbines:

i. Impulse Turbines: Pelton Turbine

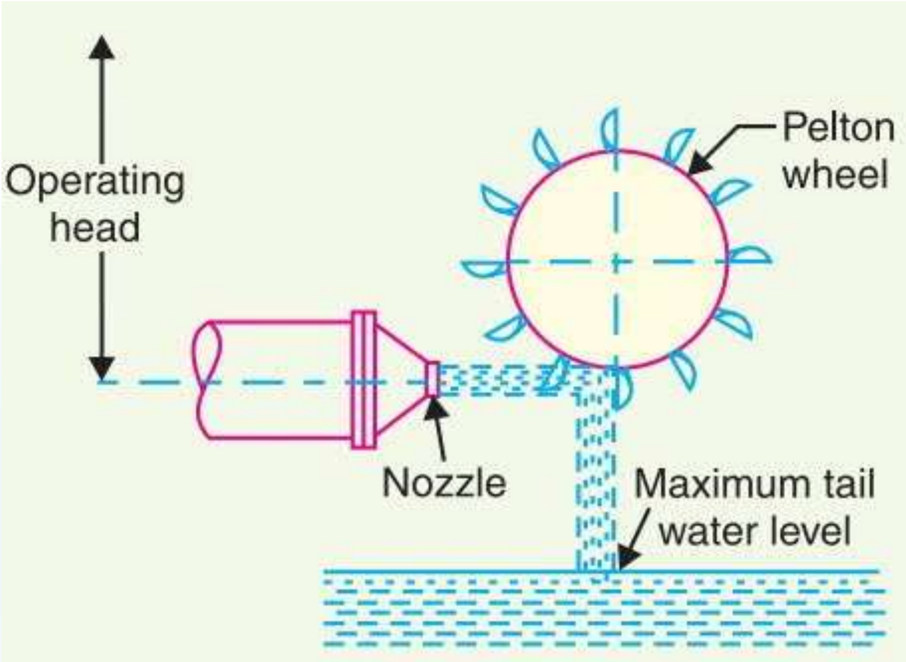


Fig. 2.4 Pelton Wheel

Main Components

2.Water Turbines:

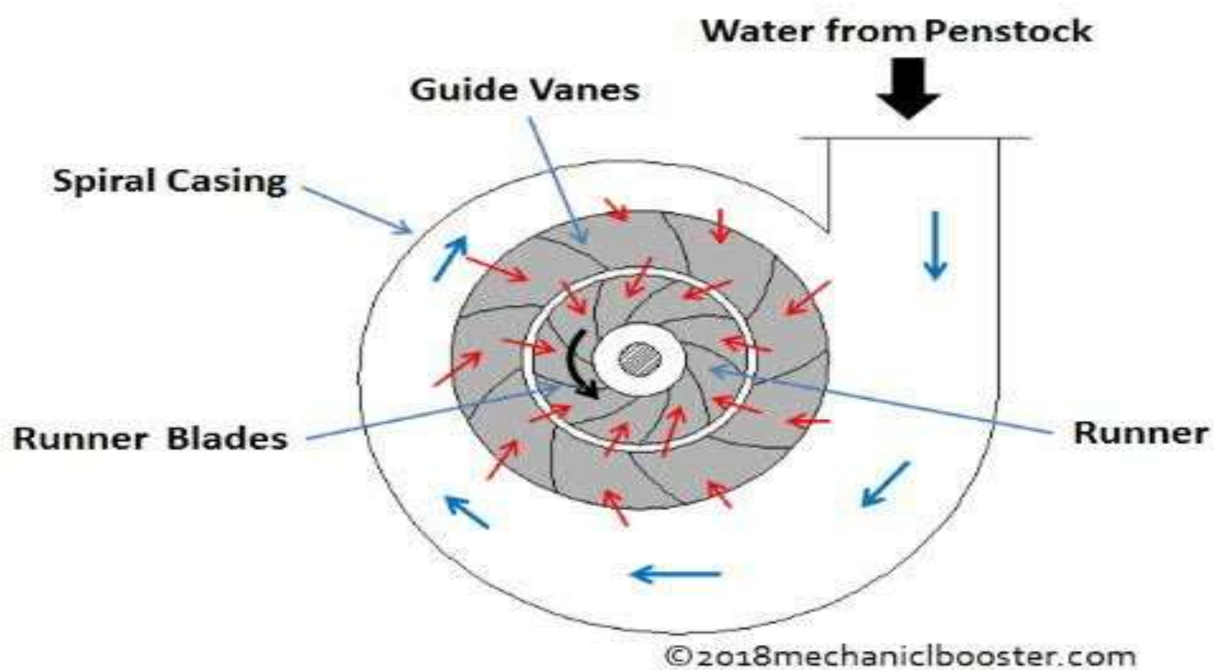
i. Impulse Turbines: Pelton Turbine

- Used for high heads.
- the entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the jet drives the wheel.
- force of water jet striking the buckets on the wheel drives the turbine.
- quantity of water jet falling on the turbine is controlled by means of a *needle or spear* (not shown in the figure) placed in the tip of the nozzle.
- Governor controls the movement of the needle to control the flow of water in the turbine.

Main Components

2.Water Turbines:

ii. Reaction Turbines: Francis and Kaplan Turbines



Reaction Turbine

Main Components

2.Water Turbines:

ii. Reaction Turbines: Francis and Kaplan Turbines

- used for low to medium heads.
- consists of an outer ring of stationary guide blades/ vanes fixed to the turbine casing and an inner ring of rotating blades forming the runner.
- Guide blades control the flow of water.
- As the water passes over the “rotating blades” of the runner both pressure and velocity of water are reduced.
- This causes a reaction force which drives the turbine.

Main Components

3.Electrical Equipments:

The electrical equipment of a hydro-electric power station includes alternators, transformers, circuit breakers and other switching and protective devices.

Here, the alternator places vertically on the turbine to give alternator protection from submersion.

Thus the turbine should tolerate high pressure here.

Advantages

(*i*) It requires no fuel as water is used for the generation of electrical energy.

(*ii*) It is quite neat and clean as no smoke or ash is produced.

(*iii*) It requires very small running charges because water is the source of energy which is available free of cost.

(*iv*) It is comparatively simple in construction and requires less maintenance.

(*v*) It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.

(*vi*) It is robust and has a longer life.

(*vii*) Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.

(*viii*) Although such plants require the attention of highly skilled persons at the time of construction, yet for operation, a few experienced persons may do the job well.

Disadvantages

- involves high capital cost due to construction of dam
- uncertainty about the availability of huge amount of water due to dependence on weather conditions
- Skilled and experienced hands are required to build the plant
- requires high cost of transmission lines as the plant is in hilly areas which are quite away from the consumers.
- Attention should be required as neighbor areas may be submerged due to any failure.
- Weather can be changed due to hydro power plant.

Mathematical Problems

Potential Energy = m * g * H Joule
Mass , m = density * volume.
Density of water =1000 kg/m ^{3}

$$Load\ Factor = \frac{Output\ Power}{Installed\ Capacity\ of\ the\ Plant}$$

$$Overall\ Efficiency = \frac{Electrical\ Output\ in\ Heat\ Units}{\boxed{\text{Potential Energy of water}}}$$

$$Plant\ efficiency = \frac{Firm\ Capacity}{Gross\ Plant\ Capacity}$$

$$Firm\ Capacity = \frac{Yearly\ gross\ output}{Hours\ in\ a\ year}$$

(Like average load)

$$Overall\ efficiency = penstock\ efficiency * turbine\ efficiency * generator\ efficiency$$

Mathematical Problems

Example 2.6. *A hydro-electric generating station is supplied from a reservoir of capacity 5×10^6 cubic metres at a head of 200 metres. Find the total energy available in kWh if the overall efficiency is 75%.*

Mathematical Problems

Example 2.7. *It has been estimated that a minimum run off of approximately 94 m^3/sec will be available at a hydraulic project with a head of 39 m. Determine (i) firm capacity (ii) yearly gross output. Assume the efficiency of the plant to be 80%.*

Mathematical Problems

Example 2.8. *Water for a hydro-electric station is obtained from a reservoir with a head of 100 metres. Calculate the electrical energy generated per hour per cubic metre of water if the hydraulic efficiency be 0·86 and electrical efficiency 0·92.*

Example 2.13. *The weekly discharge of a typical hydroelectric plant is as under :*

Day	*Sun*	*Mon*	*Tues*	*Wed*	*Thurs*	*Fri*	*Sat*
Discharge(m^3/sec)	*500*	*520*	*850*	*800*	*875*	*900*	*546*

The plant has an effective head of 15 m and an overall efficiency of 85%. If the plant operates on 40% load factor, estimate (i) the average daily discharge (ii) pondage required and (iii) installed capacity of proposed plant.

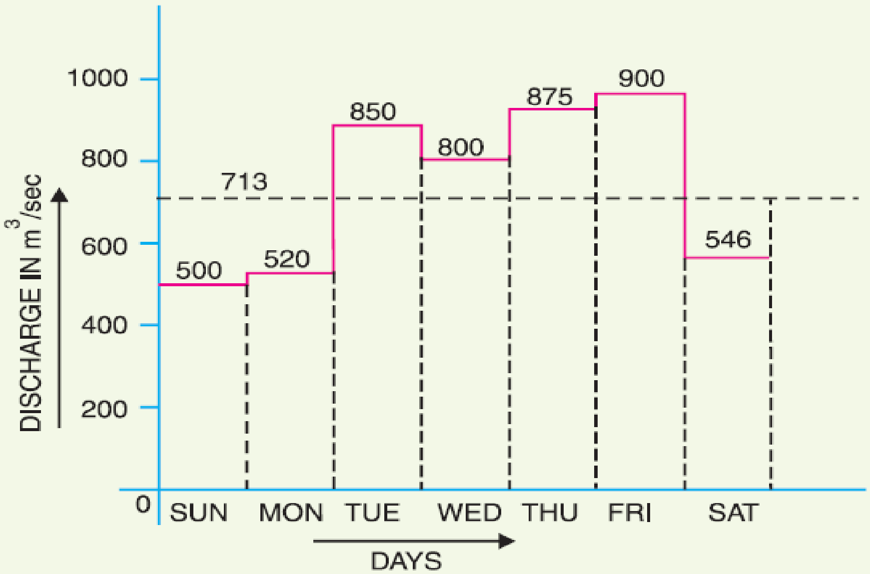


Fig. 2.5