POWER PLANT ENGINEERING

ABOUT CHAPTERS

- Coal Based Thermal Power Plants
- Diesel, Gas Turbine & Combined Cycle Power plants
- Nuclear Power plants
- Power From Renewable Energy
- Energy, Economics &Environmental Issues of power plants

World top 20 largest power plants

Rank	Station	Country	Capacity (MW)	Annual generation (TWh)	Type
1.	Three Gorges Dam	China	22,500	93.5 (2016)	Hydro
2.	Itaipu Dam	Brazil Paraguay	14,000	103.09 (2016)	Hydro
3.	Xiluodu	China	13,860	55.2 (2015)	Hydro
4.	Guri	Venezuela	10,235	47 (average)	Hydro
5.	Tucuruí	Brazil	8,370	21.4 (1999)	Hydro

6.	Kashiwazaki-Kariwa	Japan	7,965	60.3	Nuclear
7.	Grand Coulee	United States	6,809	21	Hydro
8.	Xiangjiaba	China	6,448	30.7	Hydro
9.	Longtan	China	6,426	17.3	Hydro
10.	Sayano-Shushenskaya	Russia	6,400	24.9	Hydro

11.	Bruce	Canada	6,238	47.63	Nuclear
12.	Krasnoyarsk	Russia	6,000	23.0	Hydro
13.	Hanul	South Korea	5,881	48.16	Nuclear
14.	Hanbit	South Korea	5,875	47.62	Nuclear
15.	Nuozhadu Dam	China	5,850	23.9	Hydro

16.	Zaporizhia	Ukraine	5,700	48.16	Nuclear
17.	Robert-Bourassa	Canada	5,616	26.5	Hydro
18.	Shoaiba	Saudi Arabia	5,600		Fuel oil
19.	Surgut-2	Russia	5,597	39.85	Natural gas
20.	Taichung	Taiwan	5,500	42	Coal

UNIT - I

COAL BASED THERMAL POWER PLANTS

LAYOUT OF STEAM POWER PLANT

- **Main circuits,**
  1. **Coal and Ash circuit**
  2. **Water and steam circuit**
  3. **Air and Flue gas circuit**
  4. **Cooling water circuit**

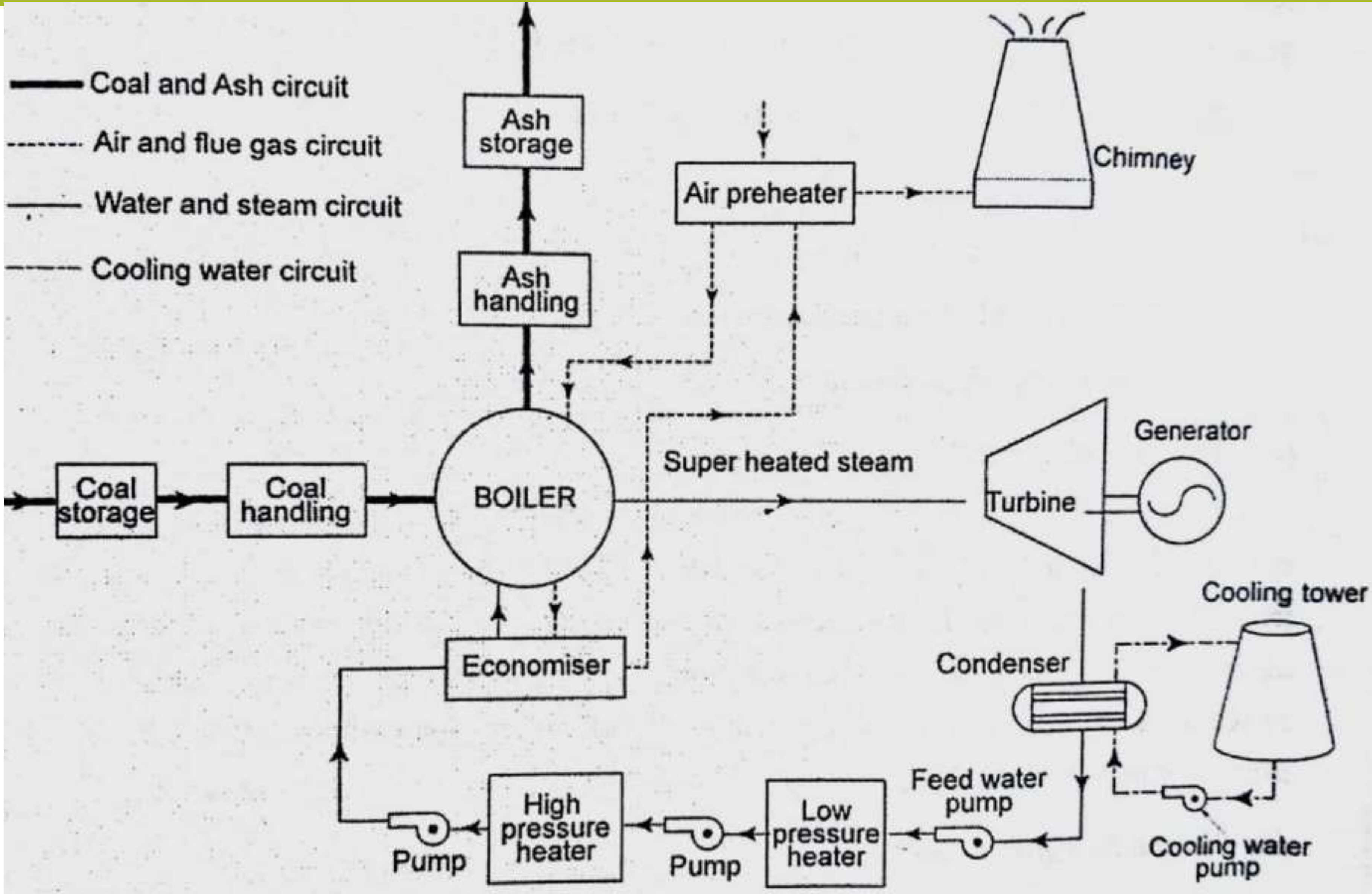


Figure 1.1 Layout of steam or thermal power plant

Advantages

- **The unit capacity of a thermal power plant is more.**
- **Life of the plant is more (25-30 years) as compared to diesel plant (2-5 years).**
- **Repair and maintenance cost are low when compared with diesel plant.**
- **Initial cost of the plant is less than nuclear plants.**

- **No harmful radioactive wastes are produced as in the case of nuclear plant.**
- **Unskilled operators can operate the plant.**
- **The power generation does not depend on water storage.**

Disadvantages

- **Thermal plants are less efficient than diesel plants**
- **Starting up the plant and bringing into service takes more time.**
- **Cooling water required is more.**
- **Space required is more**
- **Storage required for the fuel is more**
- **Ash handling is a big problem.**
- **Not economical in areas which are remote from coal fields**

High Pressure Boiler

- **The pressure range is greater than 25 bar**
- **The temperature is around 500 C**
- **Production of steam rate is more than 250** $\frac{tons}{hr}$

Advantages

i) Scale formation is eliminated due to high velocity of water through tubes

ii) Light weight tubes with better heating surface arrangement can be used

iii) The space required is less

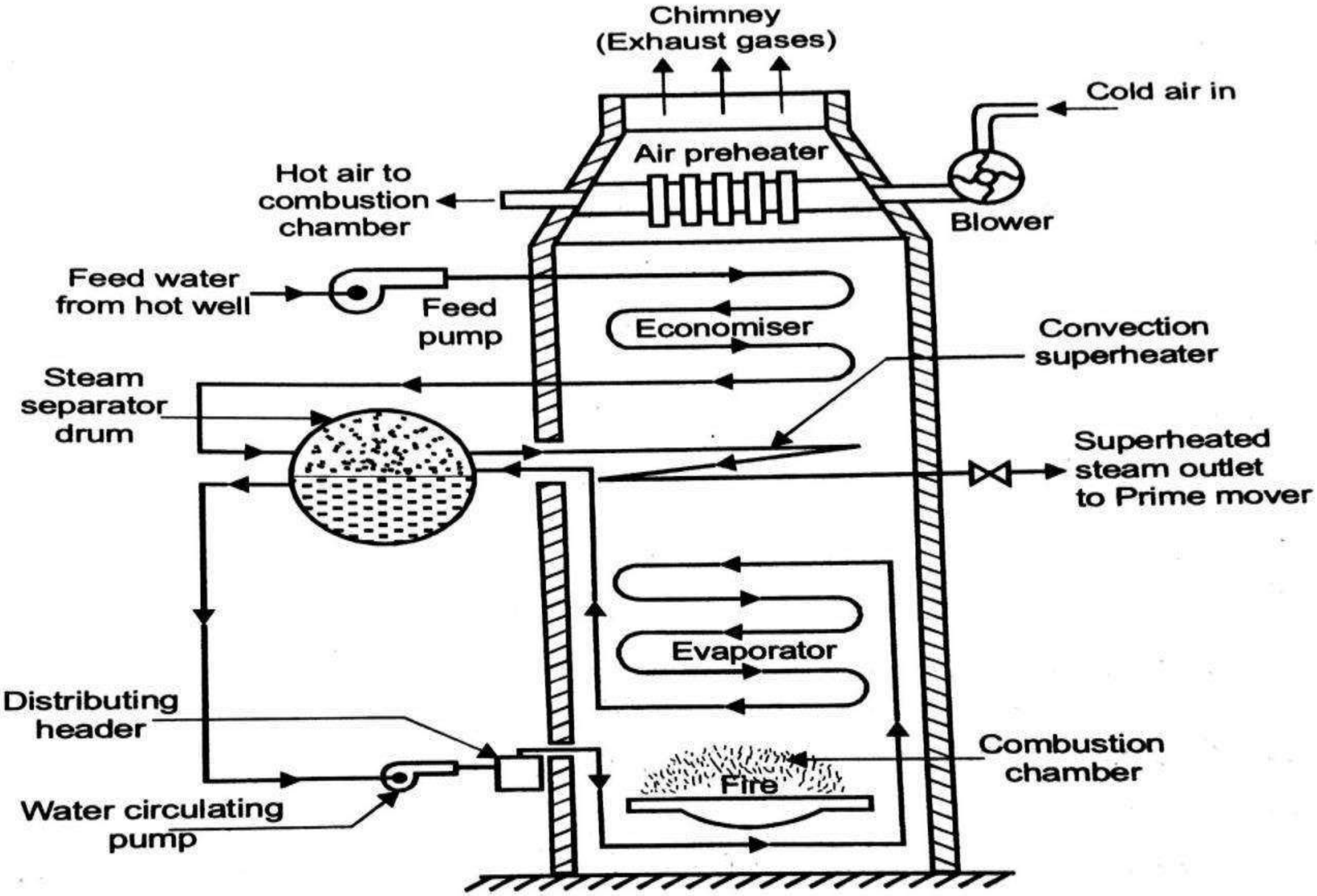
iv) All parts are uniformly heated. So over heating is reduced

v) Efficiency of power plant is increased up to 40% to 45%

Types of High pressure boiler,

- **Lamont Boiler**
- **Benson Boiler**
- **Velox Boiler**
- **Loffler Boiler**

LAMONT BOILER



BENSON BOILER

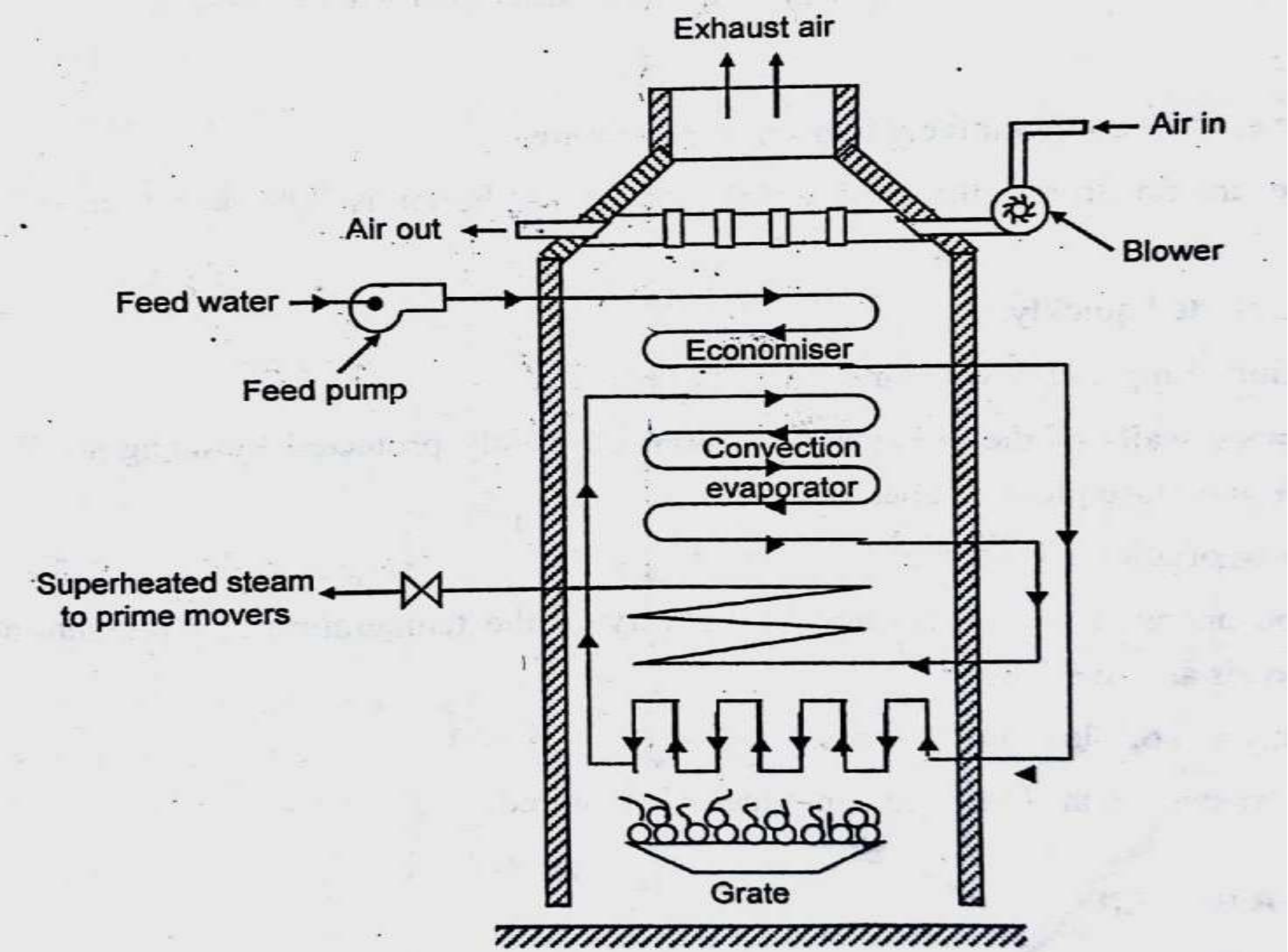
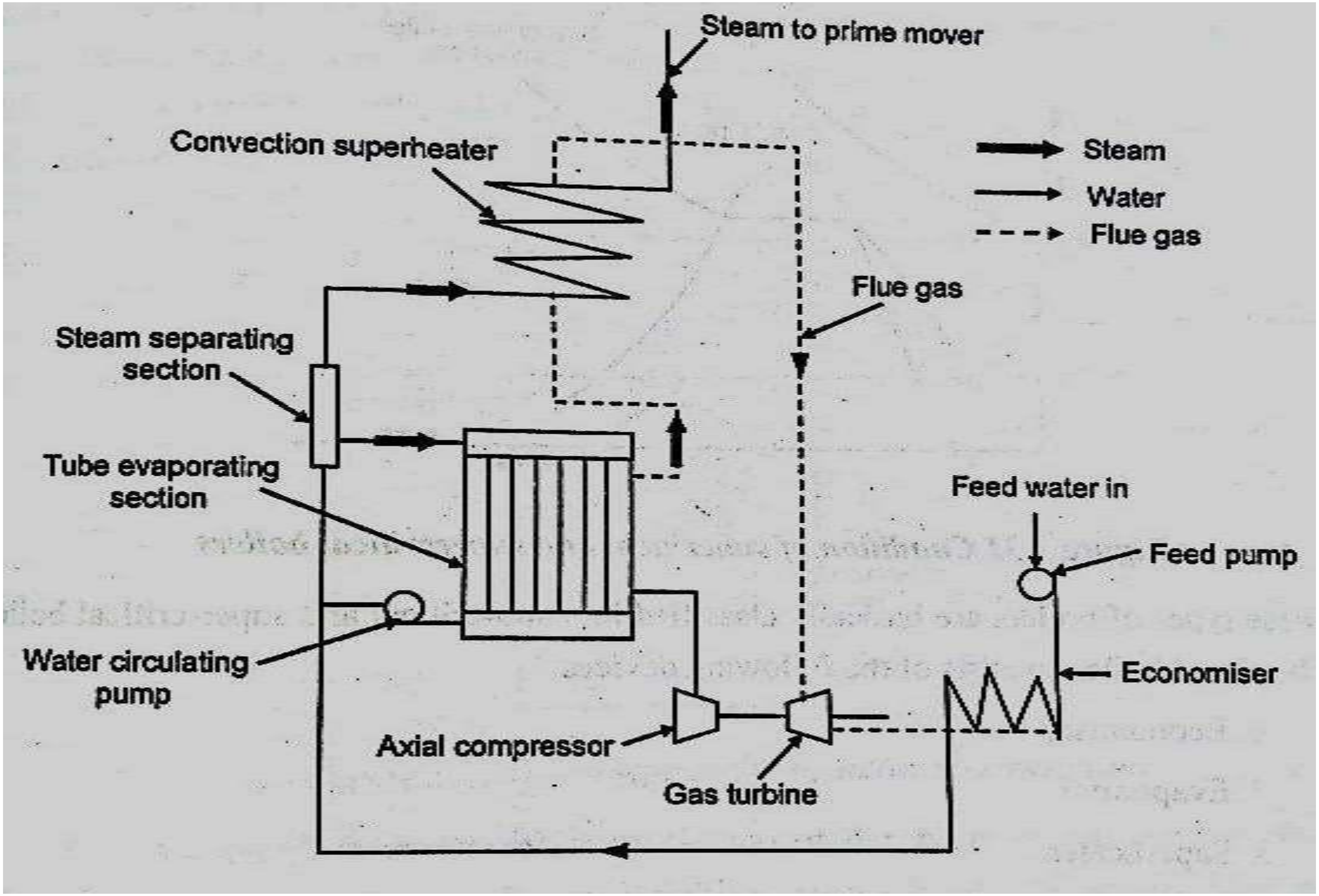
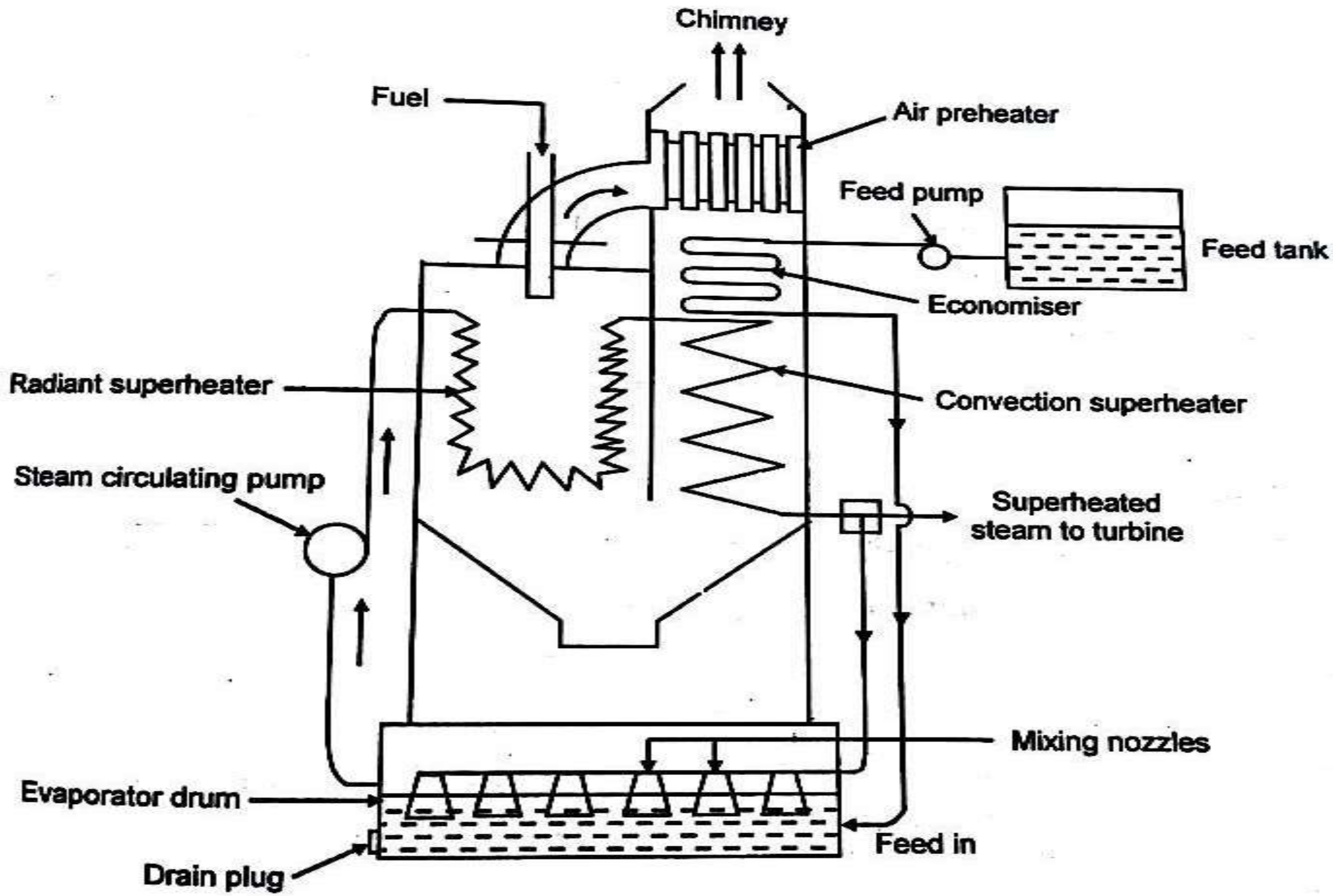


Figure 1.28 Benson Boiler

VELOX BOLIER



LOFFLER BOILER



Supercritical Boiler

- **The power plant which is operated above the critical pressure and temperature condition is called super critical boiler.**
- **Mainly, Super critical boilers are water tube boiler.**
- **The pressure range of 125 Atmospheric to 300 atmospheric & The temperature range of 510 C to 660C.**

Types of super critical Boiler,

1) Drum type boiler

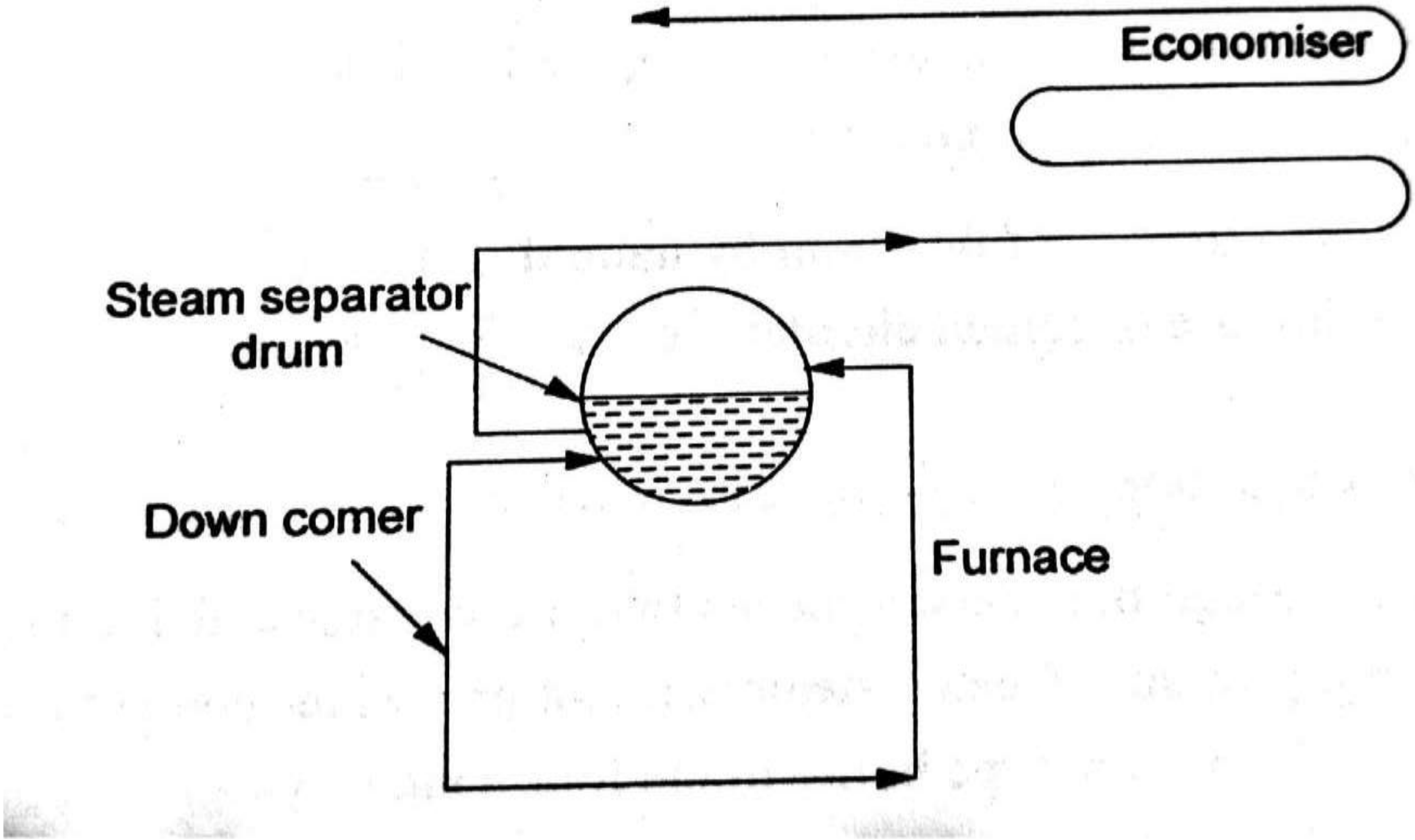
   a) Natural circulation

   b) Forced circulation

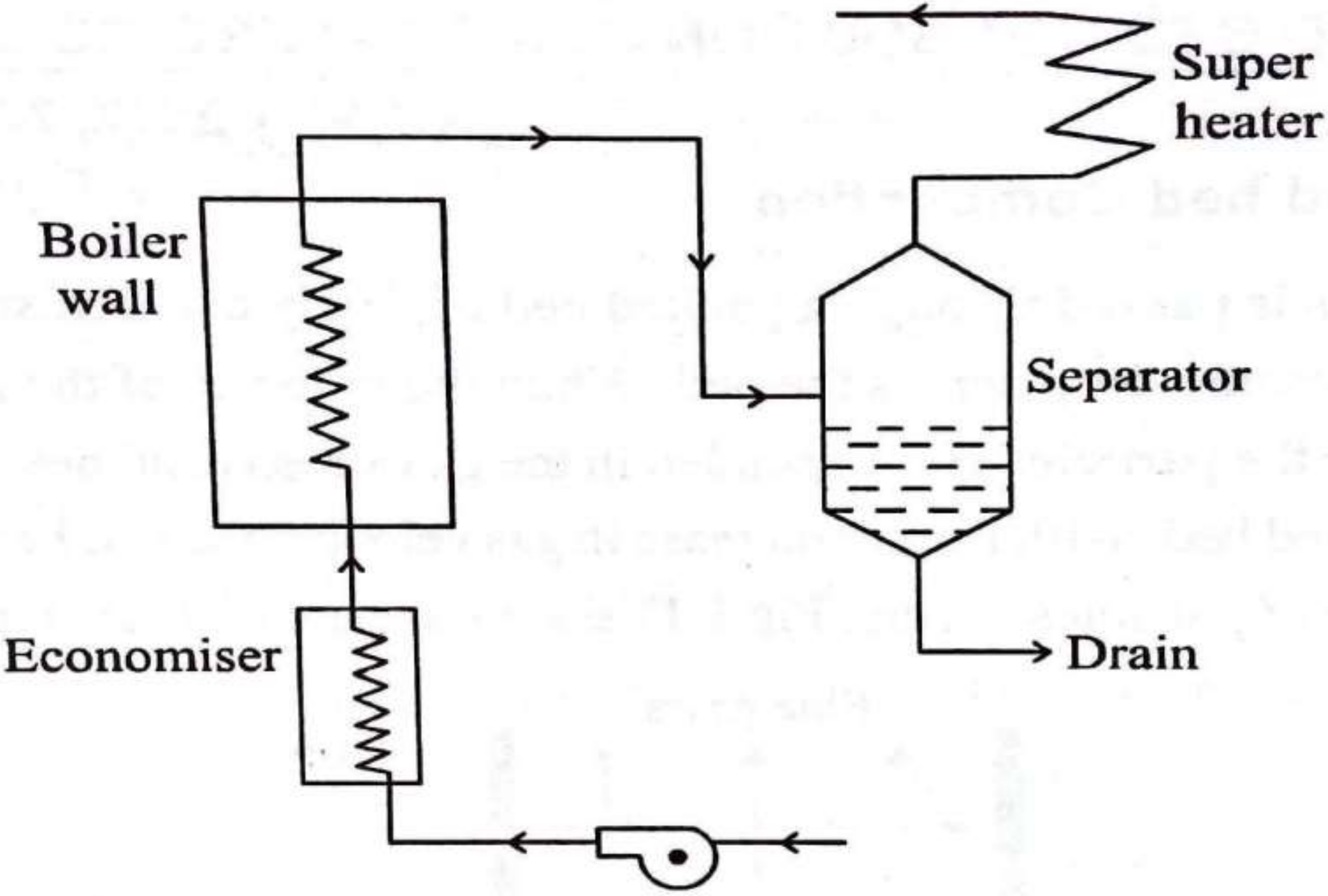
2) Once – through boiler

Drum type boiler

a) Natural circulation



Once – Through boiler



Merits:

1. It produces high thermal efficiency
2. Heat transfer rate is high.
3. The erosion and corrosion are minimized
4. It is easy to operate
5. More stable pressure level

Boiler Mounting,

- **The devices which are used for safety features and effective functioning.**

1) Pressure gauge

2) Water level indicator

3) Safety valve

4) Fusible plug

5) Blow-off cock

6) Feed check valve

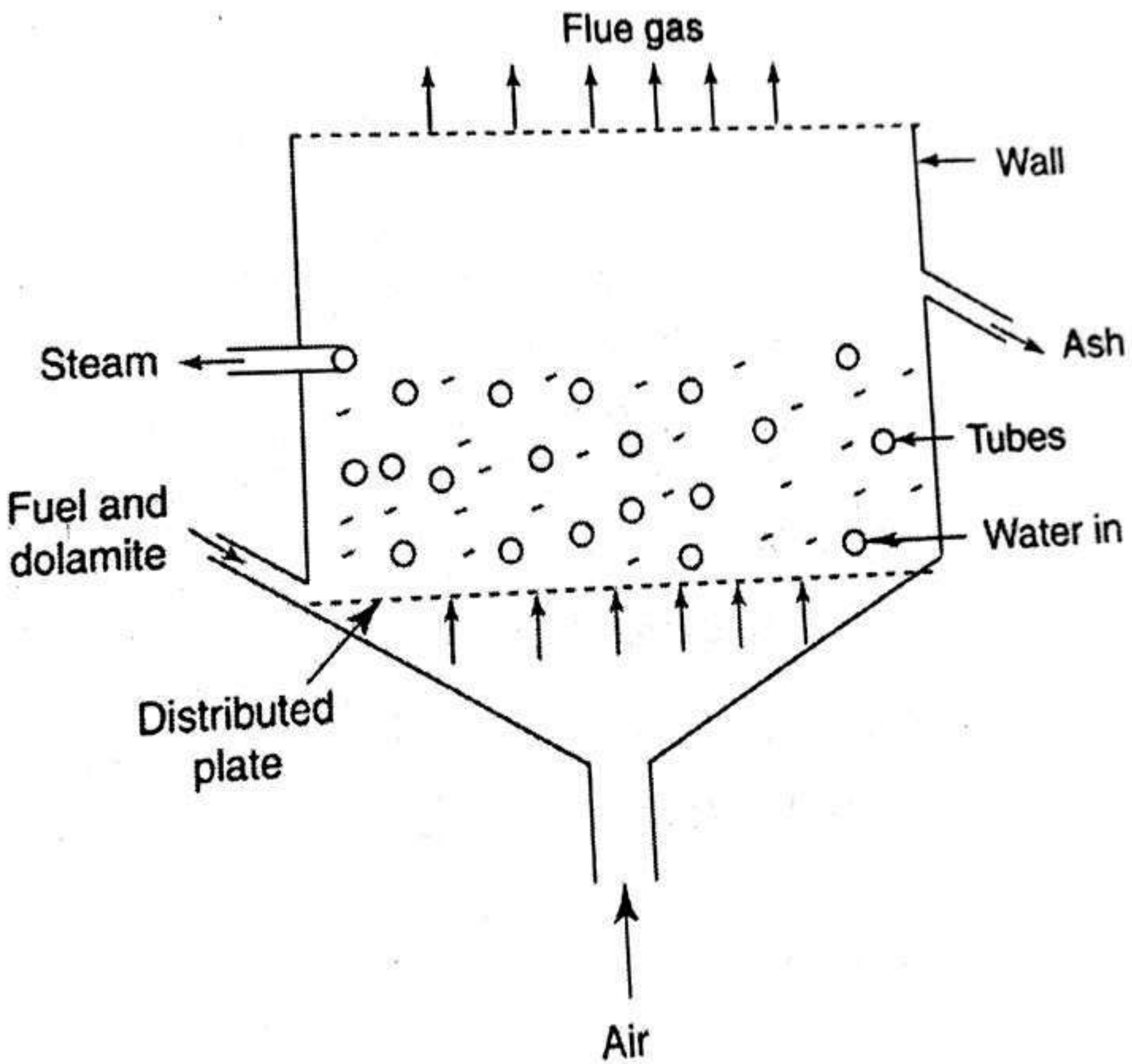
7) Man holes

Boiler Accessories,

- **The devices which are used to increase the efficiency of the boiler.**

1) Economizer
2) Air-preheater
3) Super heater
4) Steam trap
5) Deaerators

Fluidized Bed Combustion



Types of FBC Boiler

- **Boilers which are used to produce steam from fossil fuel and waste fuels by using the technique FBC are called Fluidized Bed Combustion boilers**
- **There are two types,**

  1) Bubbling Fluidized Bed Boilers(BFB)

  2) Circulating Fluidized Bed Boilers(CFB)

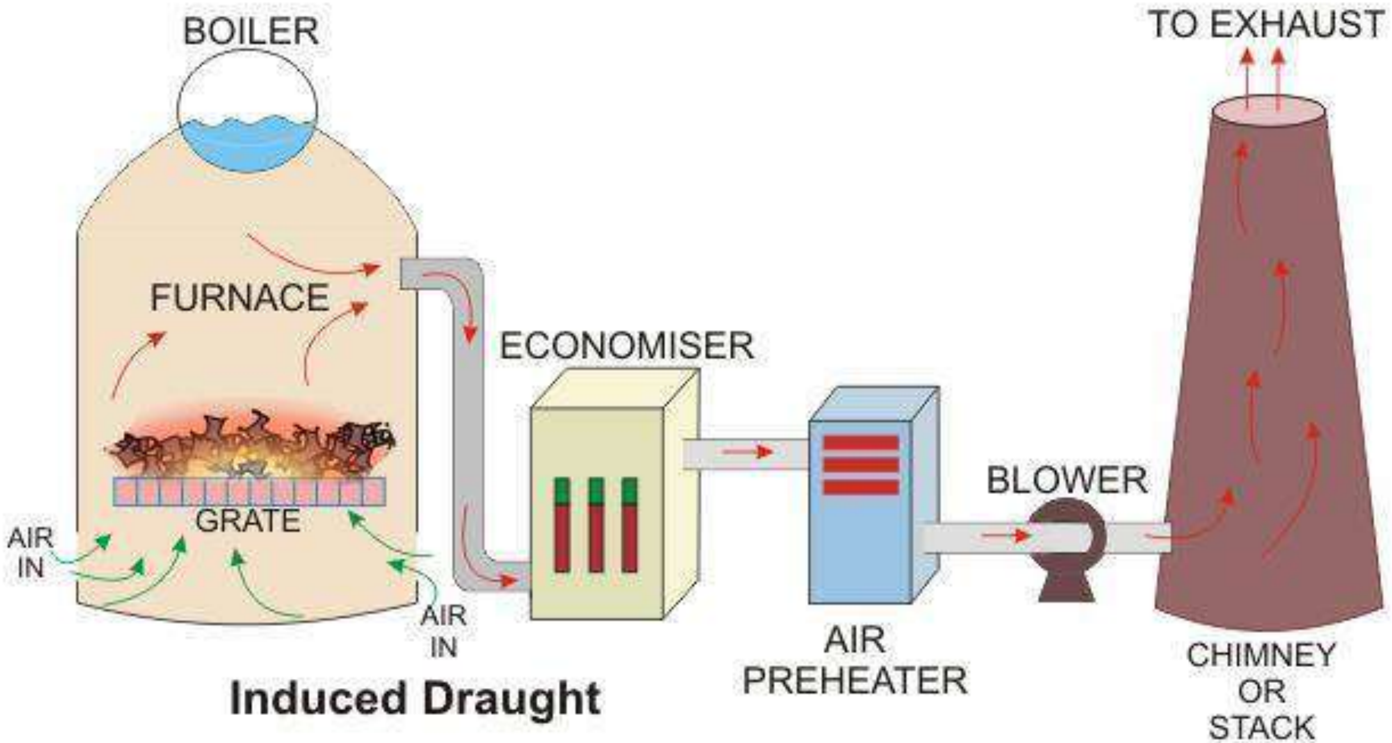
Draughts

- To supply the required quantity of air to the furnace.
- To remove the burnt products from the system.

Two types of Draughts

1. **Natural Draught**
2. **Artificial Draught**
   a) **Forced Draught fan**
   b) **Induced Draught fan**

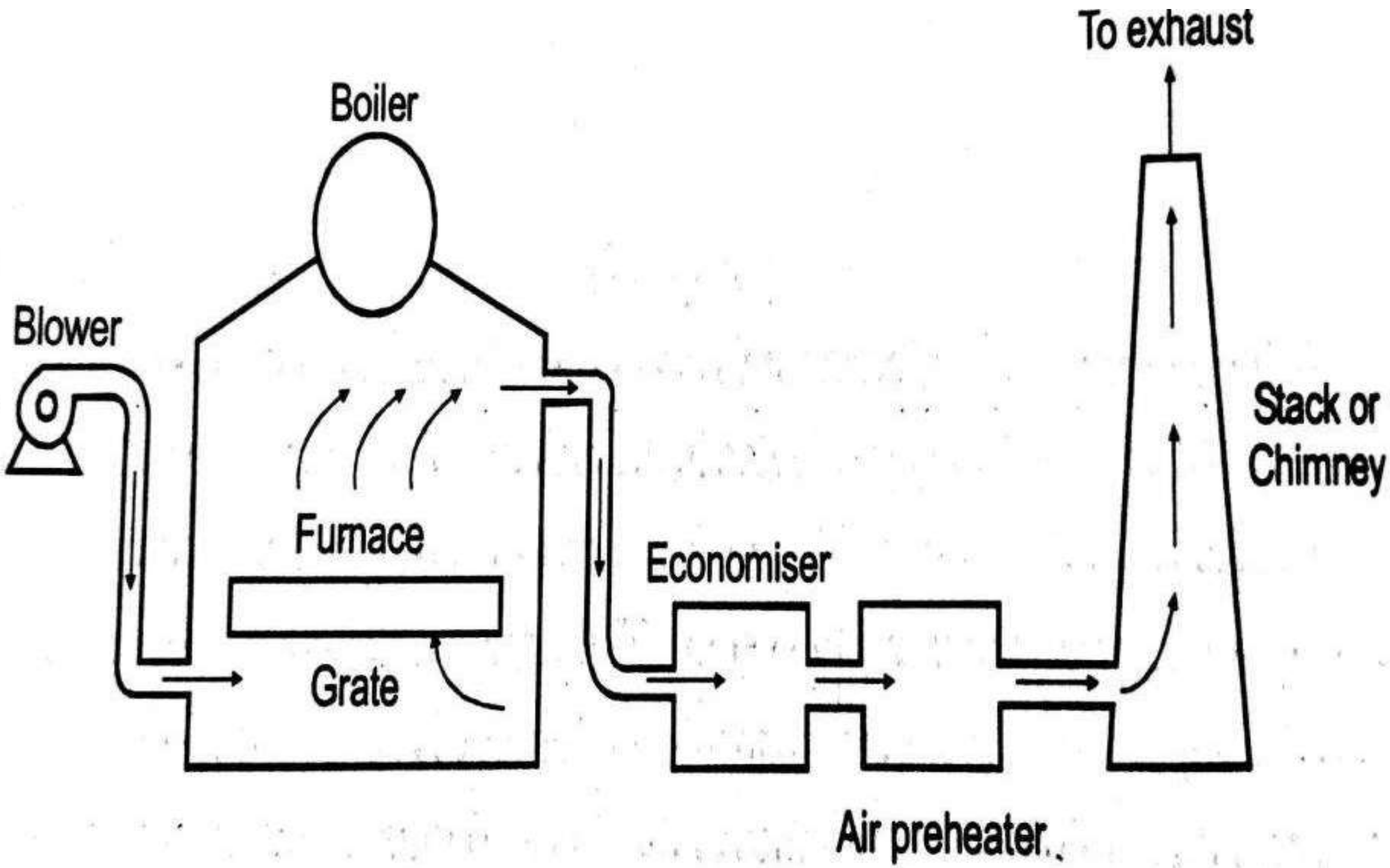
Natural Draught



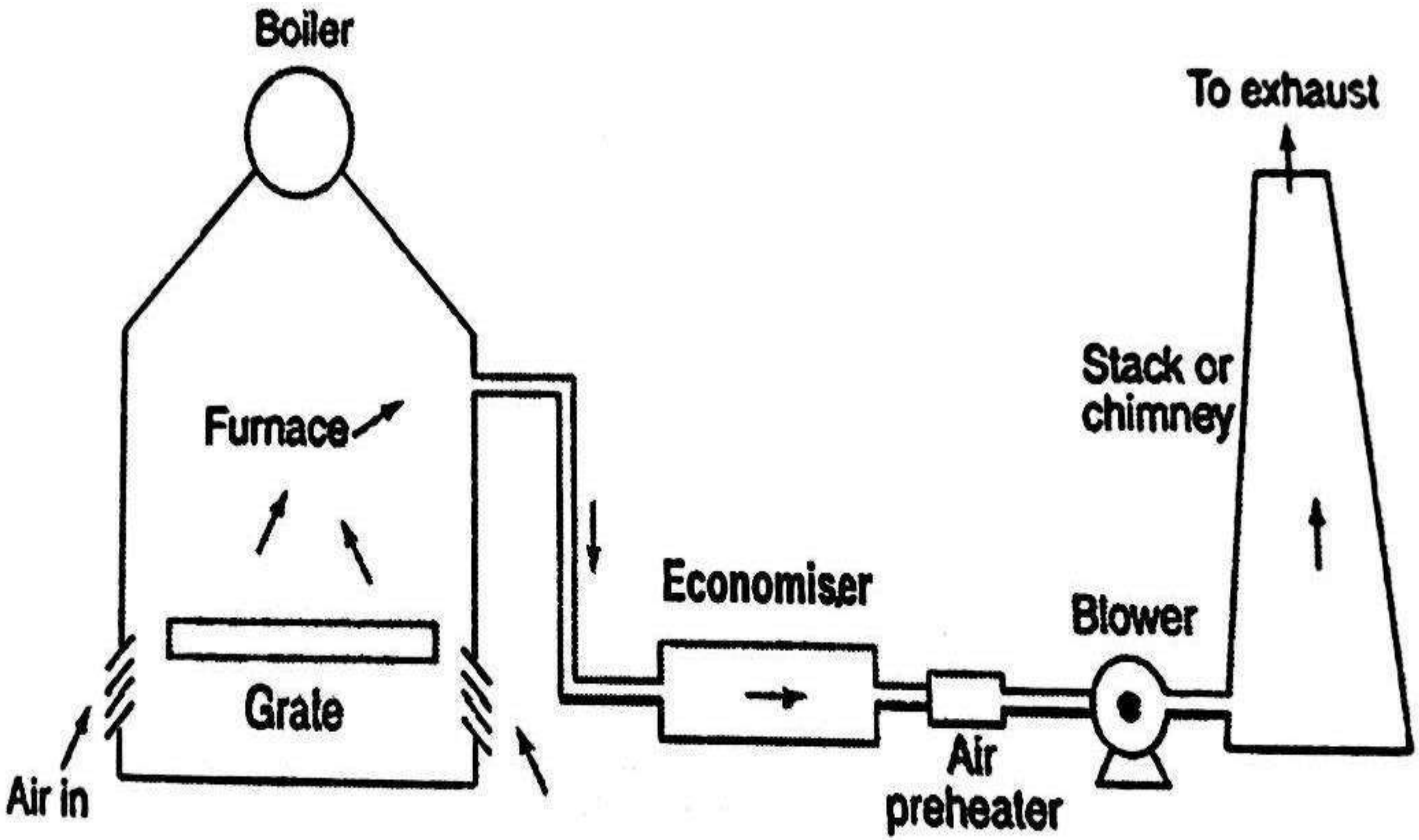
Natural Draught

- **Advantages**
  1. **Flow of air is created by chimney itself.**
  2. **No fans are needed, So the power consumption is less**
  3. **It is a self-supported structure.**
  4. **Less ground area is required.**
- **Disadvantages:**
  1. **Performance varies with seasonal change.**
  2. **Initial cost is high**

Forced draught fan



Induced draught fan



Condenser

- **Need of condenser:**

The condenser is a device which is used to convert steam into water.

Classification:

1. Based on contact

a) Surface condenser

b) Jet condenser

2. Based on type of cooling

a) Water cooled condenser

b) Air cooled condenser

3. Based on type of flow

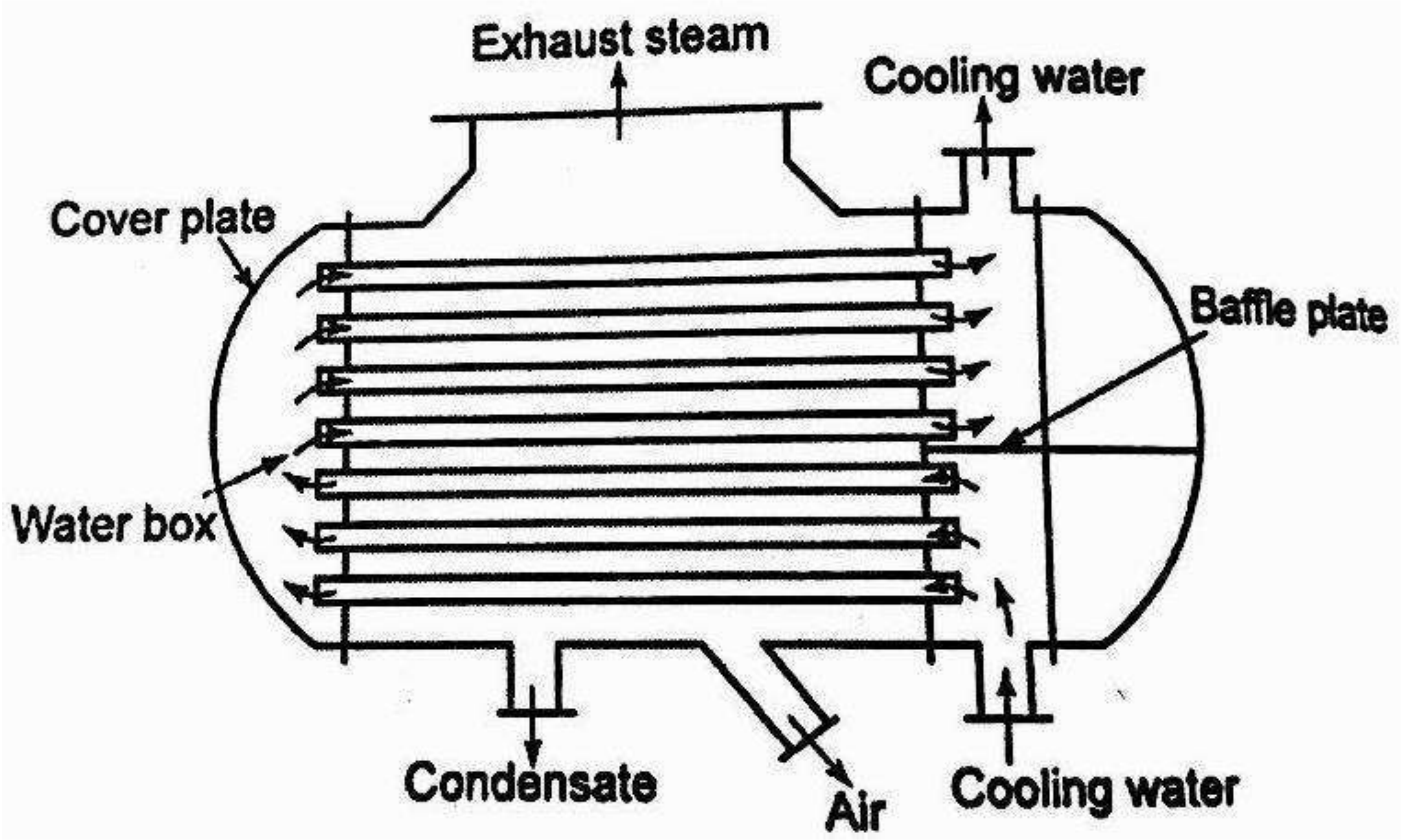
a) Down flow condenser

b) Central flow condenser

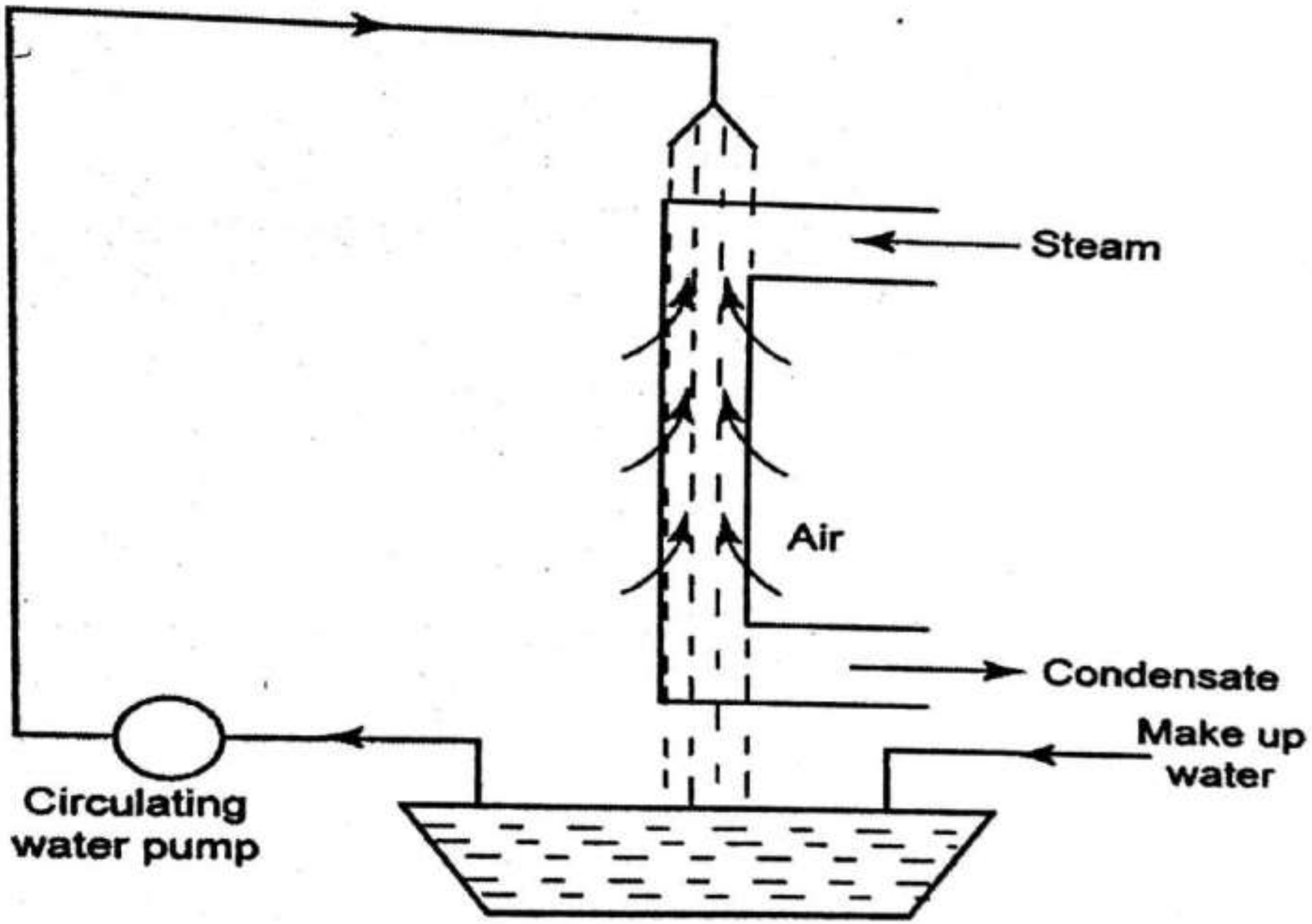
c) Evaporation condenser

Surface Condenser

1) Down flow condenser



2) Evaporation Condenser



Advantages of surface condenser

1. High vacuum can be obtained in the surface condenser.
2. To increase the thermal efficiency of the plant.
3. The condensate can be used as boiler feed water.
4. Even poor quantity of cooling water can be used.

Disadvantages of surface condenser

1. It is bulky and therefore, it requires more space.
2. The capital cost is more
3. Maintenance cost & Running cost are high.

Cooling Towers

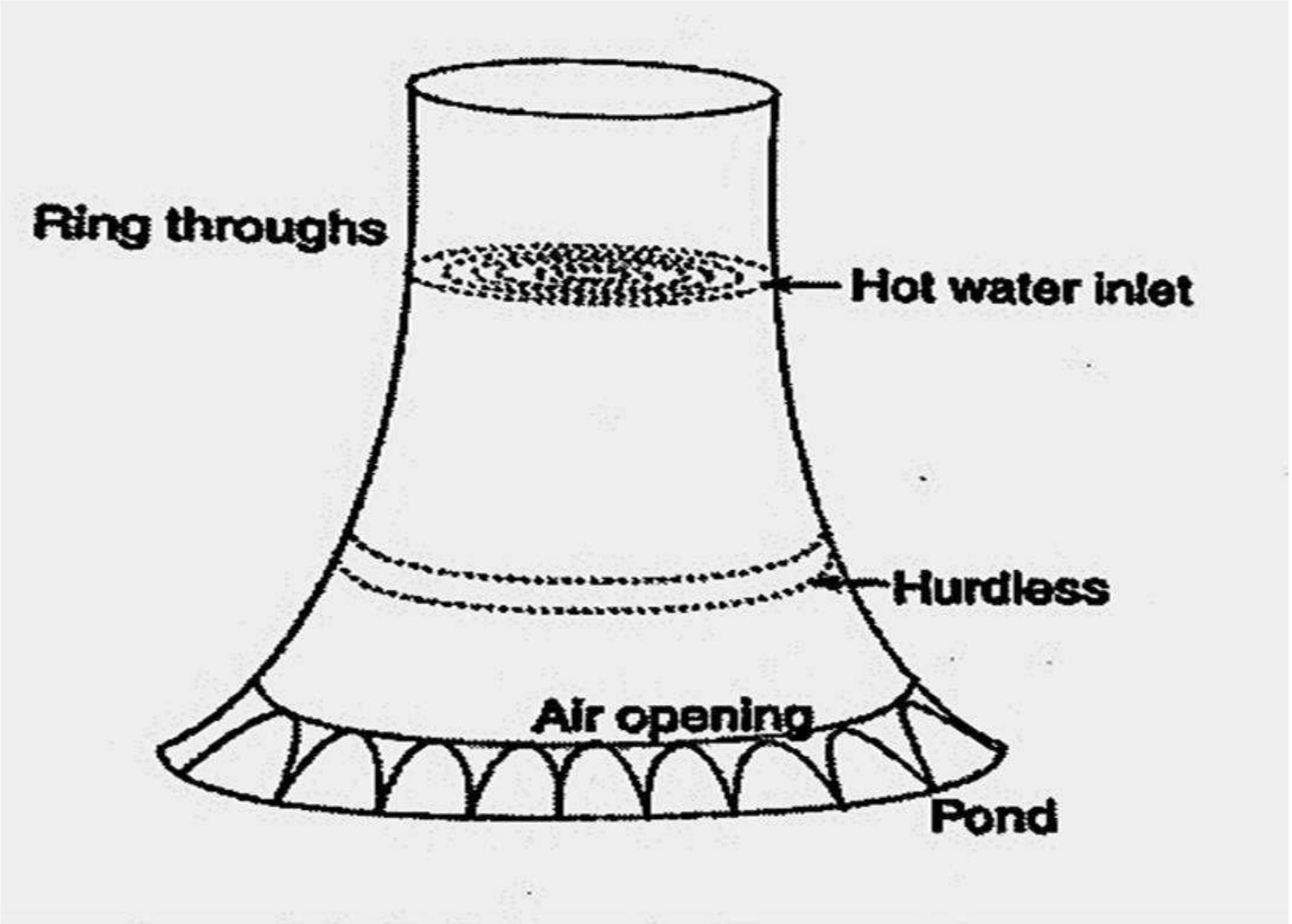
Purpose of cooling Tower,

- It is used to control the temperature of water required for the plant.
- It is reduced the water consumption of the plant.

Types,

1) Wet type
2) Dry type

Hyperbolic Cooling Tower



Dust Collector

- **To avoid the atmosphere pollution the fly ash must be removed from the gaseous products before they leave the chimney.**

Types,

1) Mechanical Dust Collector

a) Gravitational separator

b) Cyclone separator

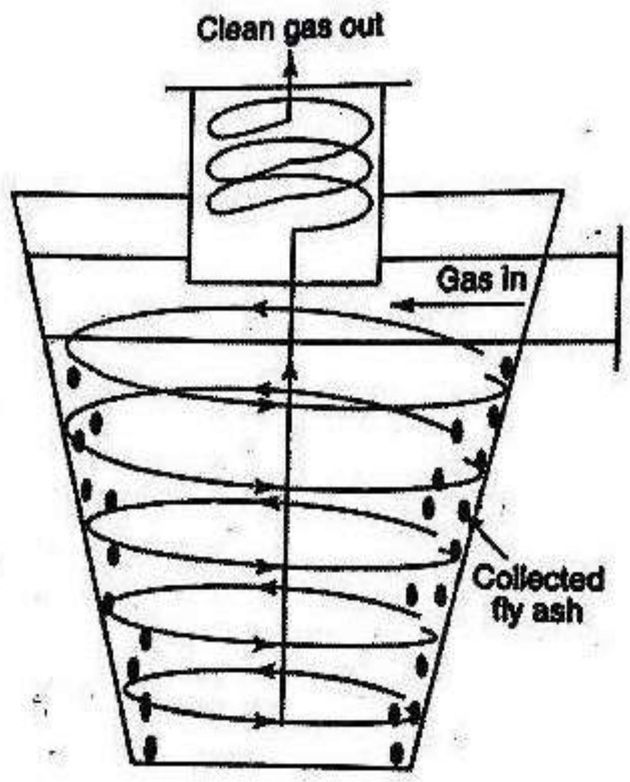
c) Scrubber

d) Electro static precipitator(ESP)

2) Electrical Dust Collector

Cyclone Separator

- **The overall efficiency of the Cyclone separator is depending on the dust particles size. Some of these values are given**



- **Advantages:**
  - i) **Efficiency is higher when large size particles are collected**
  - ii) **Maintenance cost is less.**
  - iii) **Efficiency increases.**
- **Disadvantages:**
  - i) **It requires more power than other collectors.**
  - ii) **The pressure loss is high.**

Ash Handling System

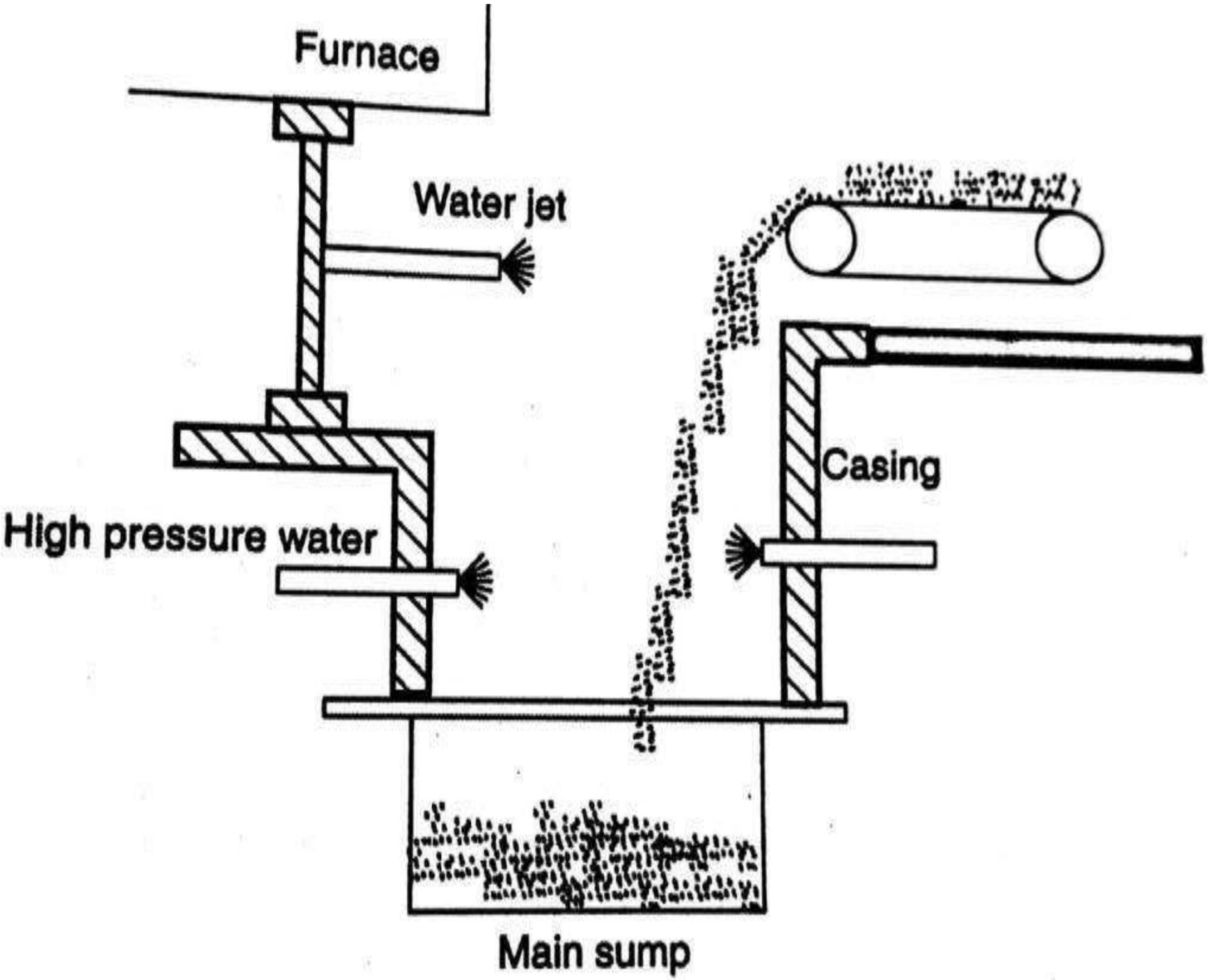
Ash Handling System

A) Hydraulic system:-

It can be divided into two group,

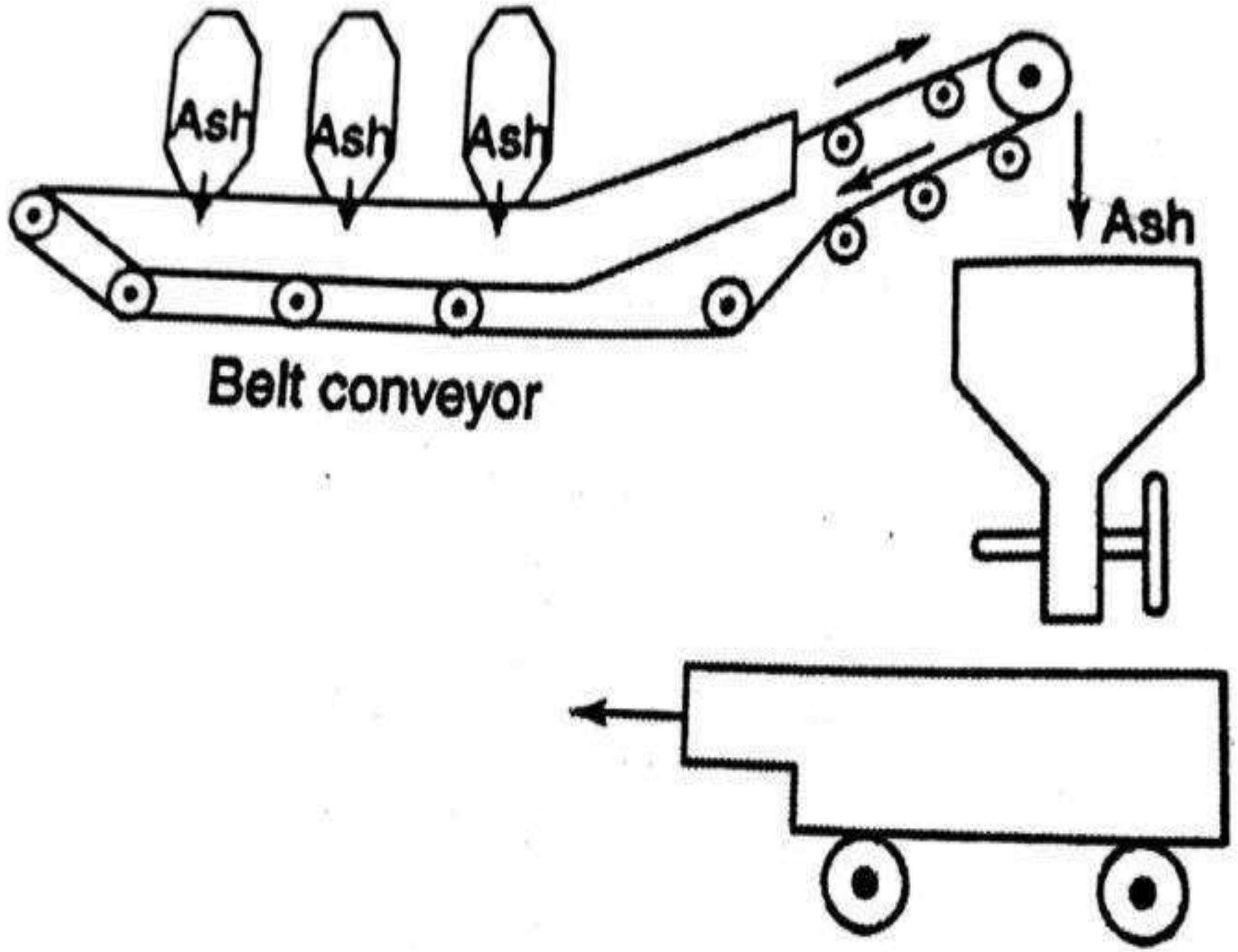
1) Low velocity system

2) High velocity system

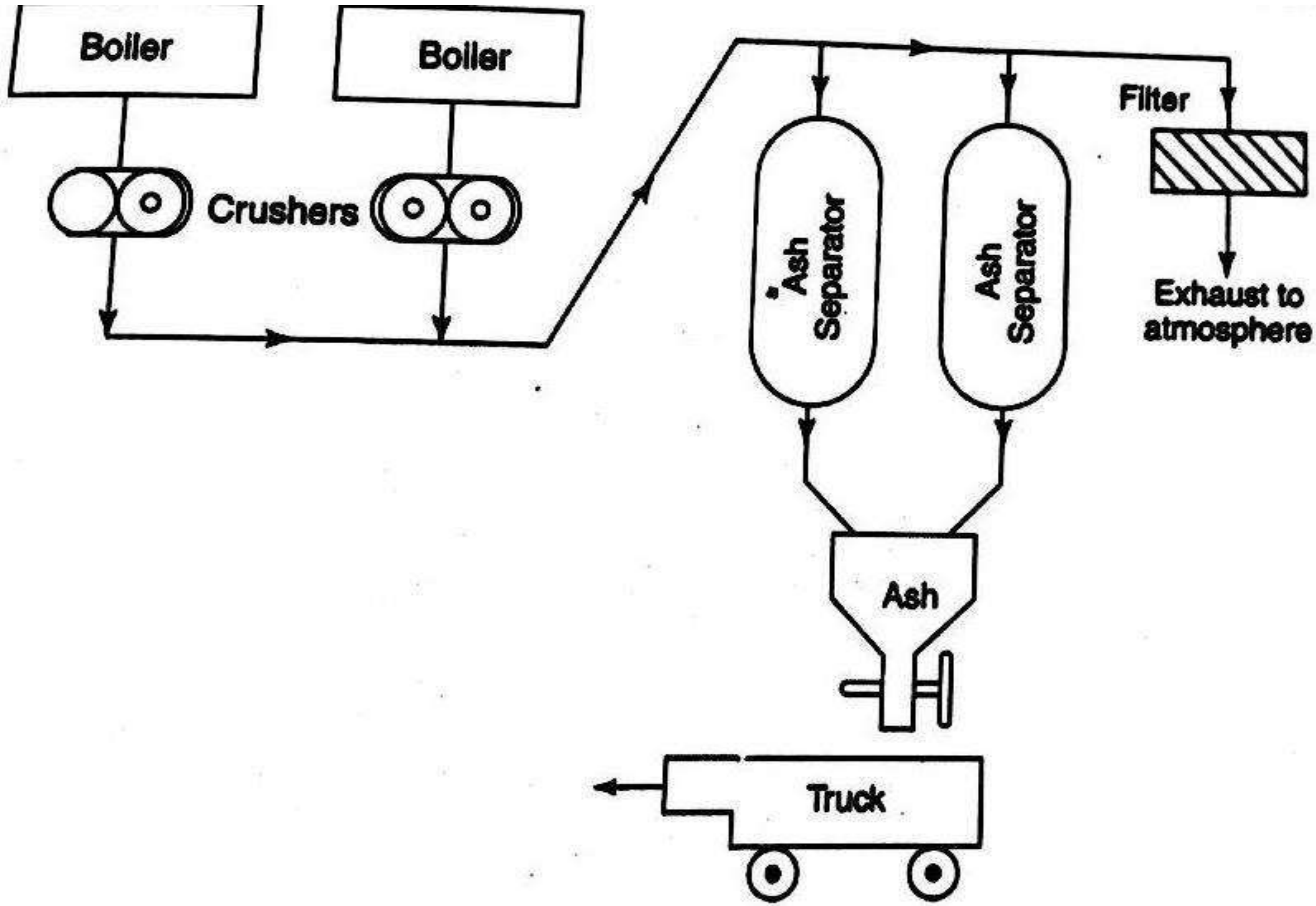

Furnace
Water jet
Casing
High pressure water
Main sump

Advantages:

1. **Ash carrying capacity is high.**
2. **The whole system is clean.**
3. **Total system is enclosed**
4. **Discharge of ash is at considerable distance**
5. **Working parts are not contact with ash**


Ash
Ash
Ash
Ash
Belt conveyor

C) Vacuum extraction system:



Cogeneration

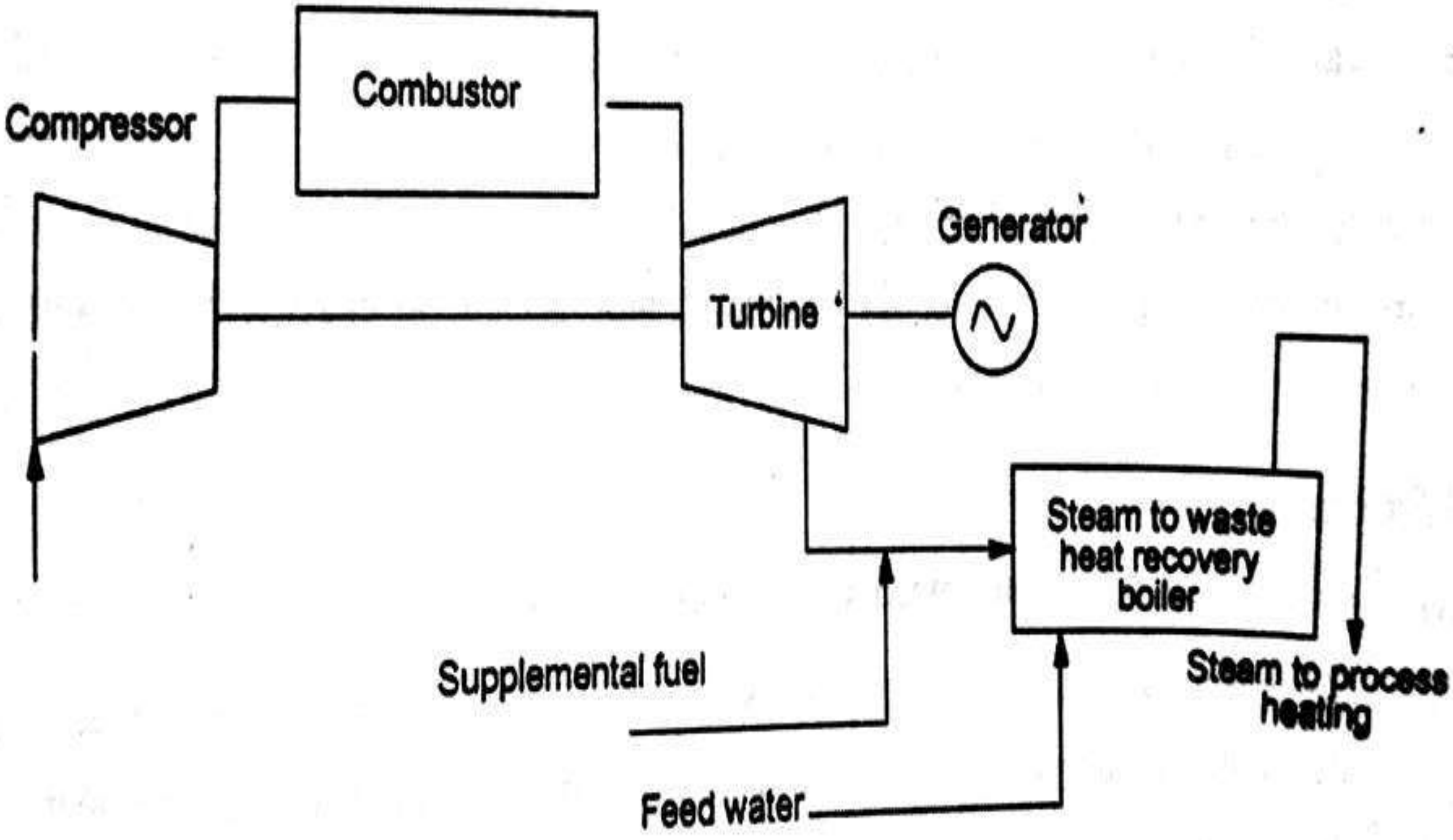
- **It is also called combined heat power(CHP)**
- **For producing different form of energy by using a single source of fuel.**
- **The fuel may be natural gas, oil, diesel, wood and coal**

Two types of cogeneration power plants,

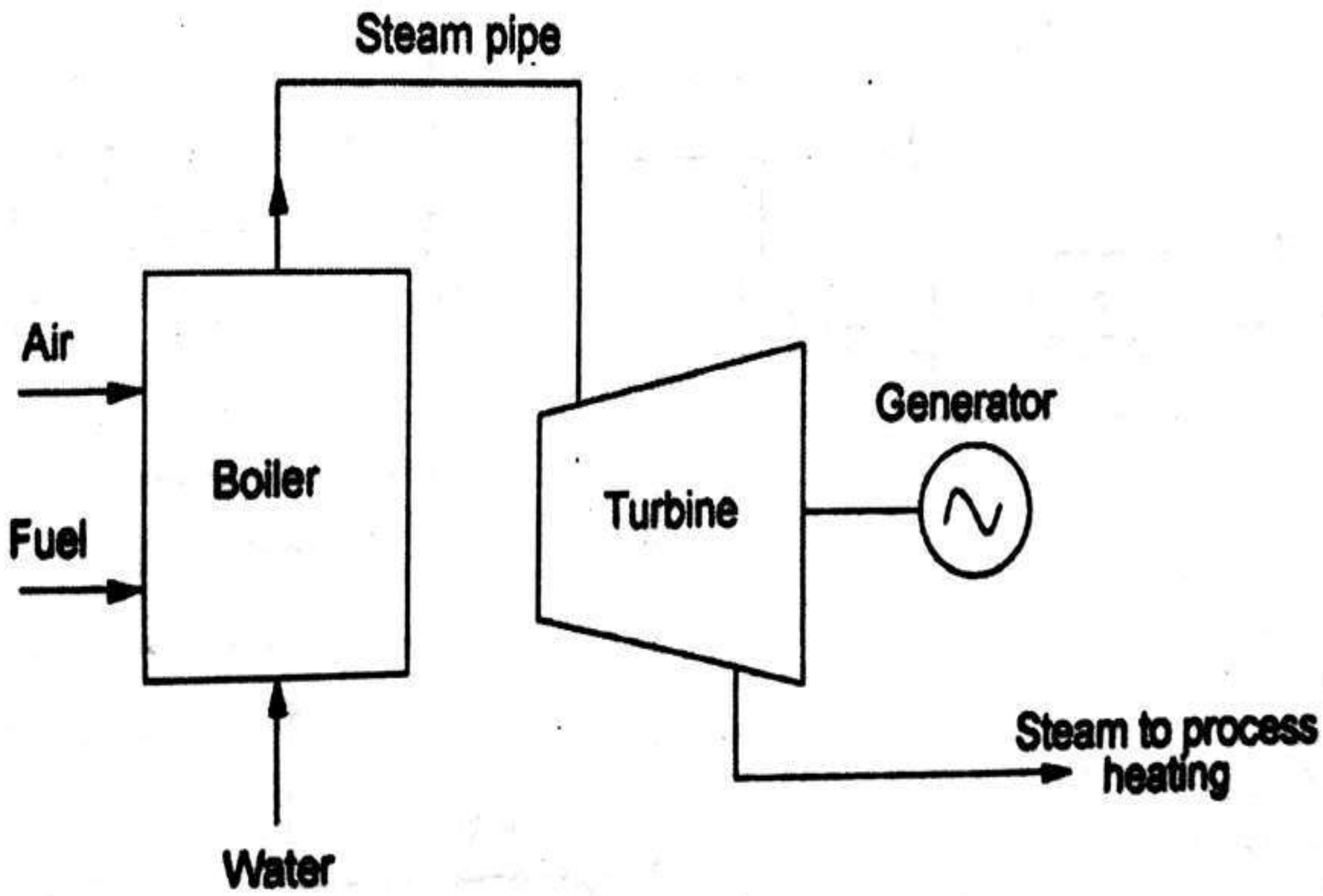
1) Topping cycle power plant

2) Bottoming cycle power plant.

Gas Turbine Topping CHP plant



Steam Turbine Topping CHP plant



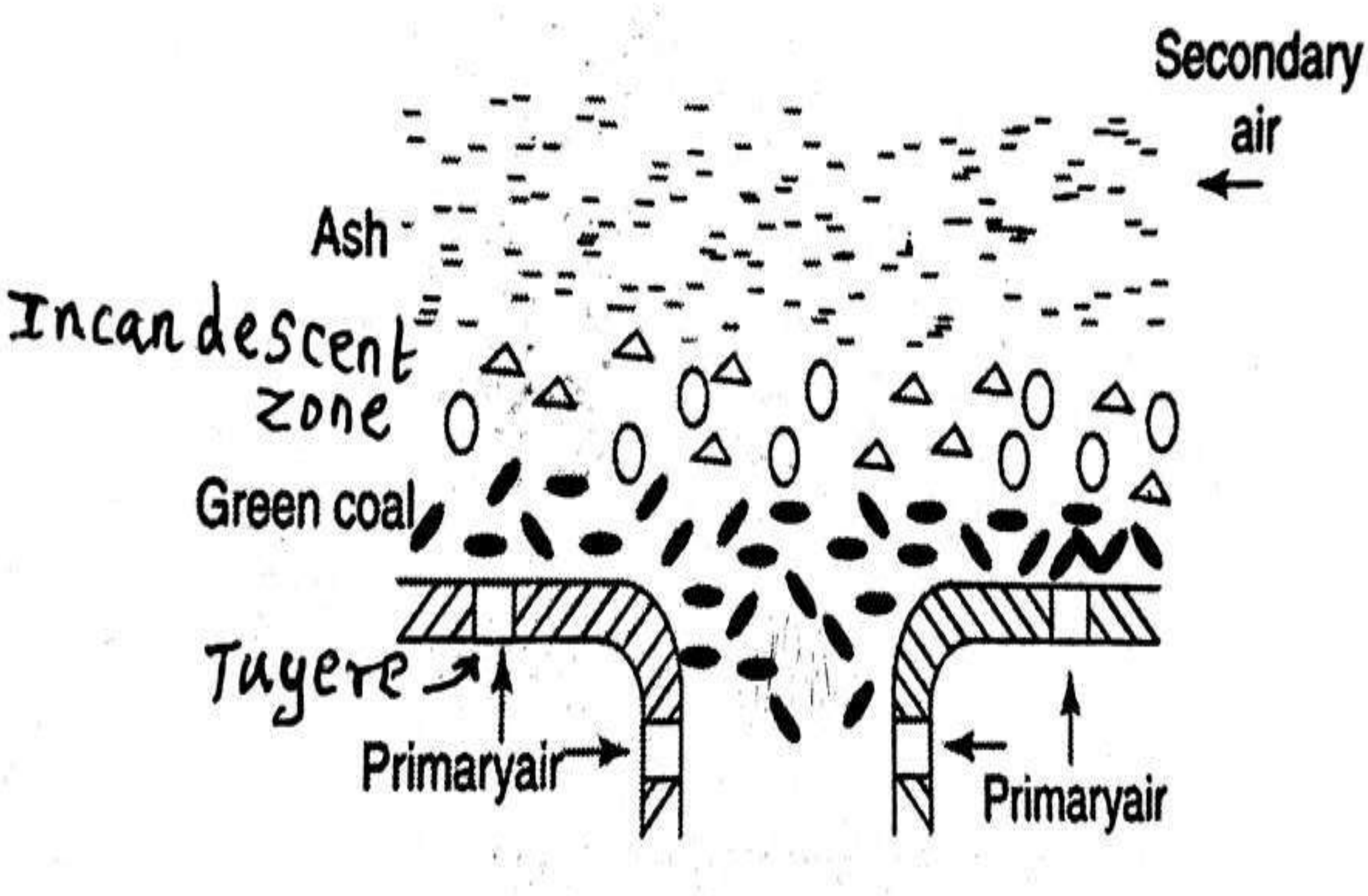
STOKERS

- **Stokers are used for feed solid fuels into the furnace in medium and large size power plants**
- **Classified into two types,**

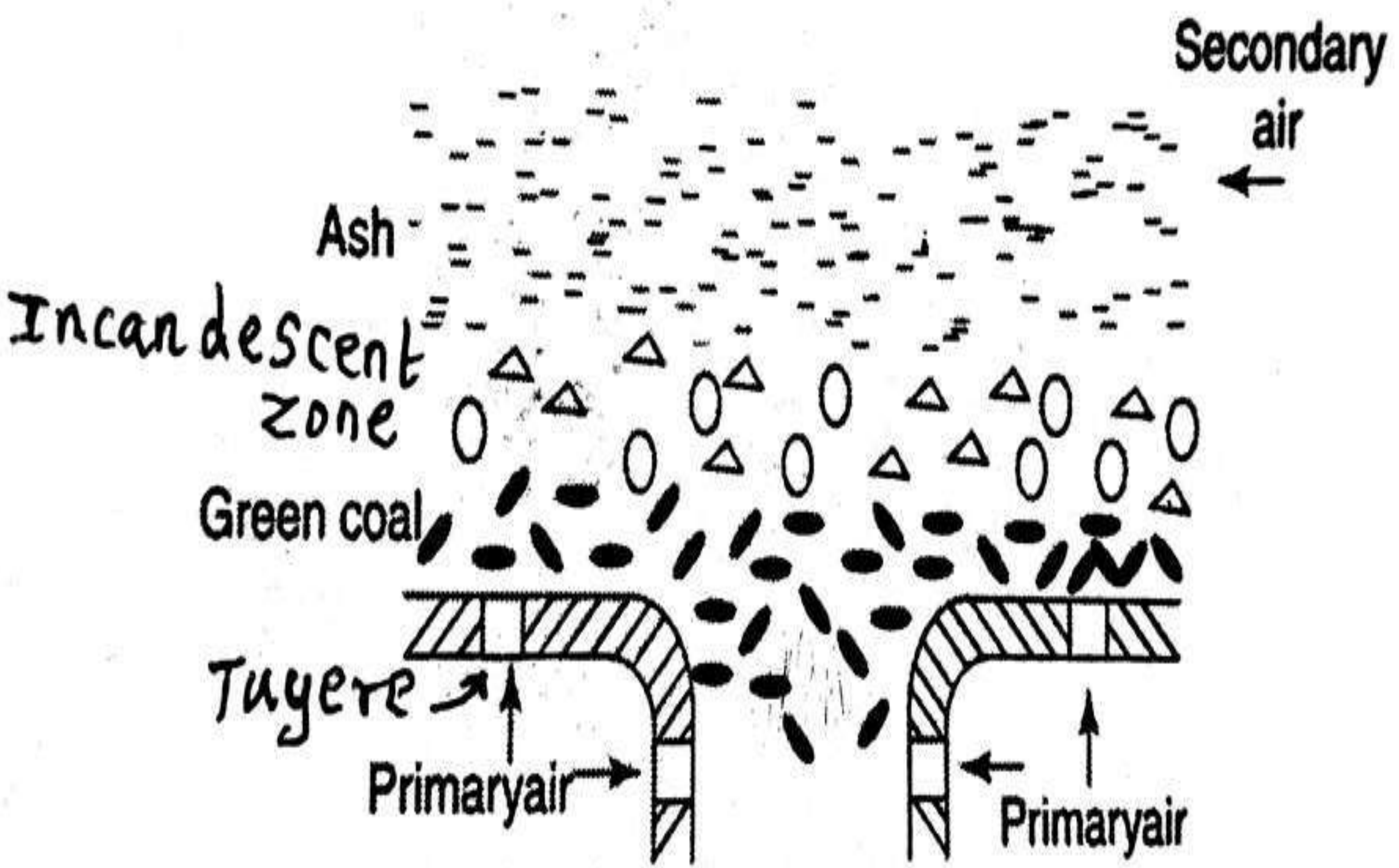
  1) Over feed stokers

  2) Under feed stokers

Over feed stokers



Under feed stokers



Advantages:

1) **Part load efficiency is high**
2) **It has high thermal efficiency**
3) **It has self-cleaning grates**
4) **Variety of coals can be used**
5) **It is more suitable for variable air conditions.**

Coal Handling System

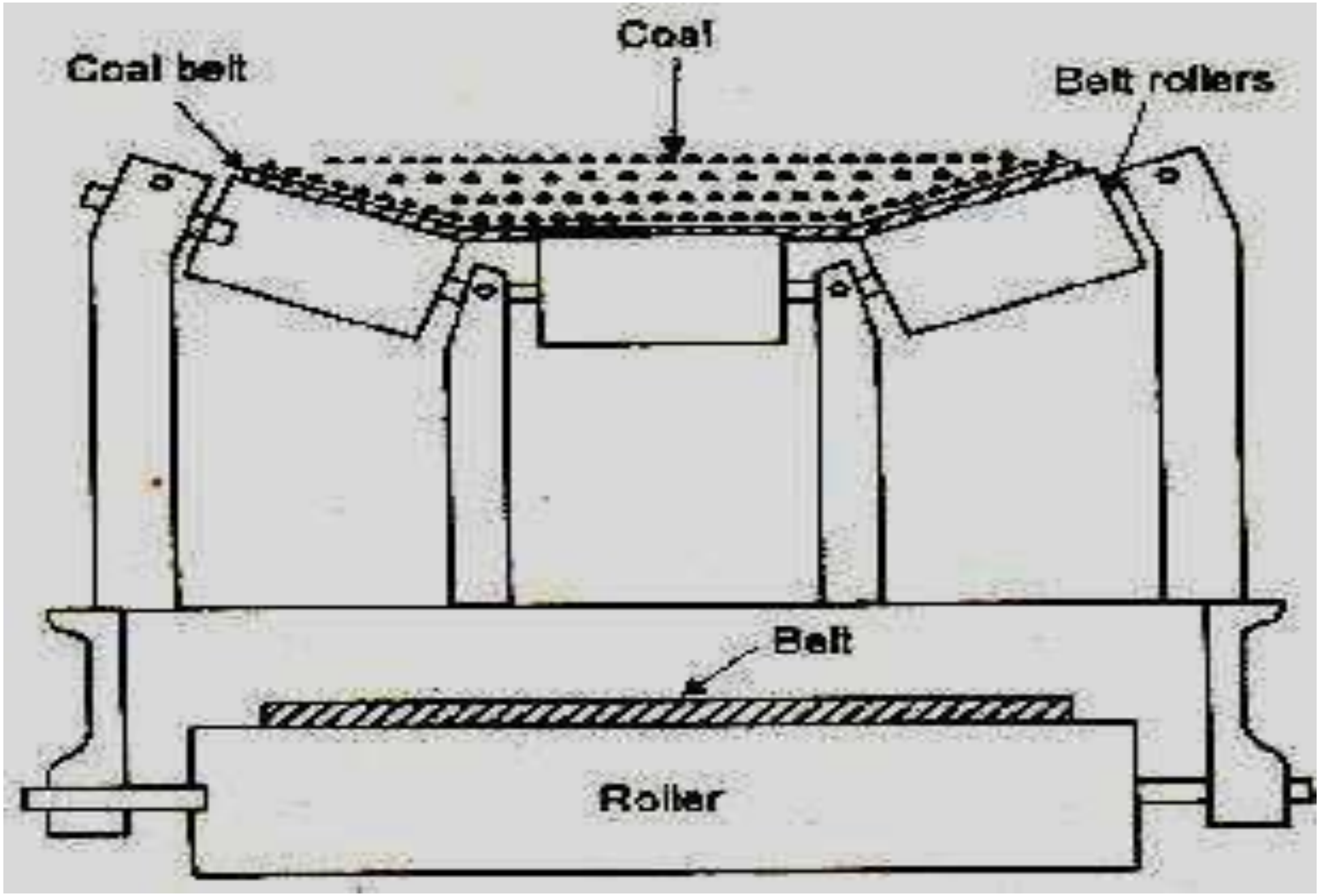
The various steps involved in coal handling are as follows:

- **Coal delivery.**
- **Unloading**
- **Preparation**
- **Transfer**
- **Outdoor storage**
- **Covered storage**
- **In-plant handling**
- **Weighing and measuring**
- **Feeding the coal into furnace.**

Transfer:

- **After preparation coal is transferred to the dead storage by means of the following systems.**
  - **Belt conveyors**
  - **Screw conveyors**
  - **Bucket elevators**
  - **Grab bucket elevators**
  - **Skip hoists**
  - **Flight conveyor**

BELT CONVEYOR

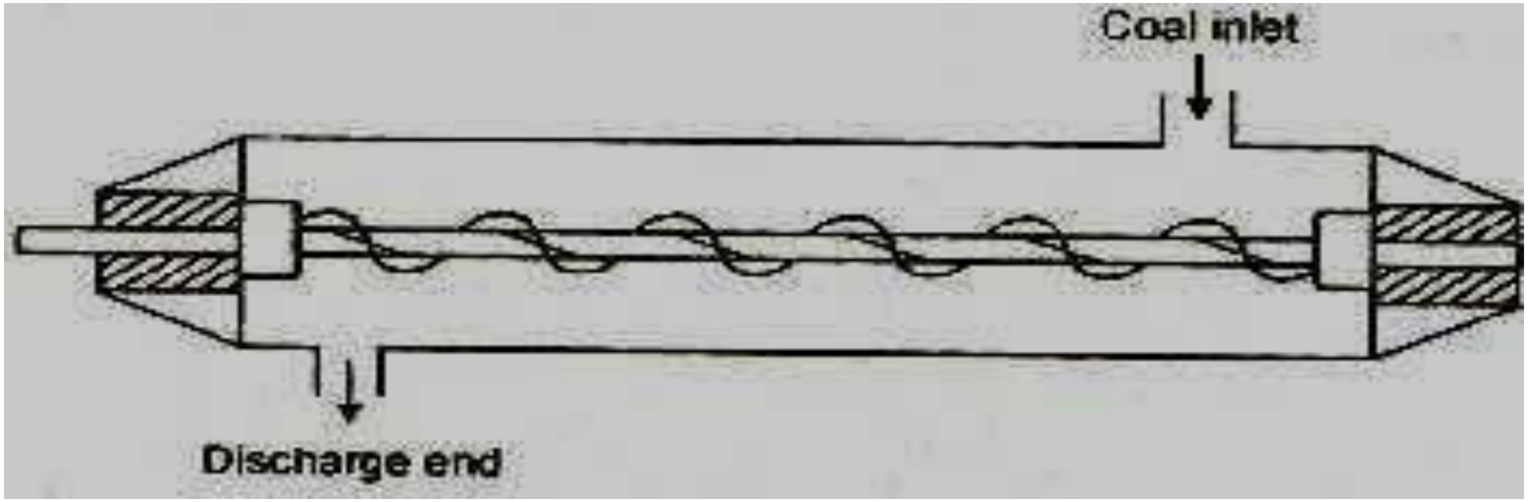


Advantages of belt conveyor:

- **It requires less power as compared to other types of systems**
- **Large quantities of coal can be discharged quickly and continuously.**
- **Material can be transported on moderate inclines.**
- **Its operation is smooth and clean**

Screw Conveyor

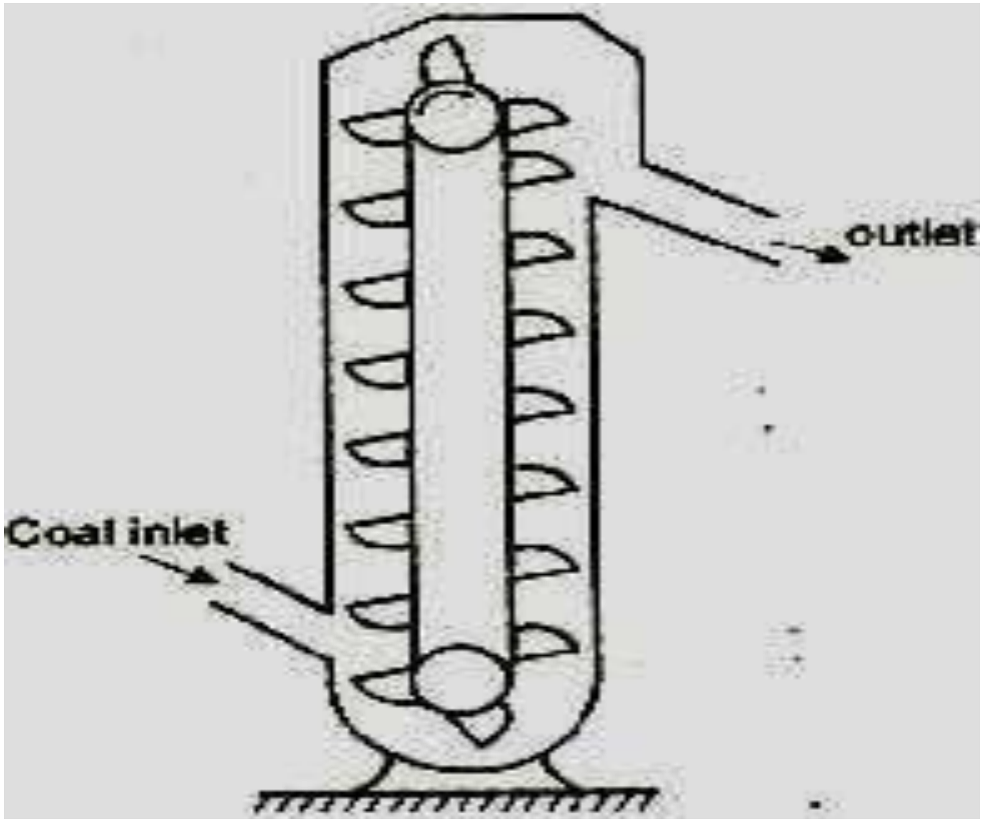
- **It consists of an endless helicoid screw fitted to a shaft. The screw while rotating in a trough transfers the coal from feeding end to the discharge end.**



- **This system is suitable, where coal is to be transferred over shorter distance and space limitations exist.**
- **The initial cost of the consumption is high and there is considerable wear screw.**
- **Rotation of screw varies between 75-125 rpm.**

Bucket elevator:

- It consists of buckets fixed to a chain. The chain moves over two wheels.The coal is carried by
- the bucket from bottom and discharged at the top.



Feed Water Treatment

Three main objectives,

- **Continuous Heat Exchange**
- **Corrosion production**
- **Production of high quality steam**

Necessity To Treat The Raw Water

- **The deposition of dissolved salts and suspended impurities will form scale on the inside wall.**
- **The harmful dissolved salts may react with various parts of boiler.**
- **Corrosion damage may occur in turbine blades**

Types Of Feed Water Treatment

1. External Treatment
2. Internal Treatment

1. Internal Treatment

a) Sodium carbonate (Soda ash) treatment

b) Phosphate treatment

c) Blow down

- Sodium carbonate reacts with sulphate and phosphate react with calcium sulphate.

2) External treatment:

a) Mechanical treatment

b) Thermal treatment

c) Demineralisation treatment

d) Chemical treatment

a) Mechanical treatment

- **Aluminium sulphate or Sodium sulphate dissolve with water**

b) Thermal treatment

- **This method mainly used for to remove the unwanted gases, like CO_2 and O_2 (up to 110 C)**

3) Demineralisation treatment

- **To remove the minerals from the water**

4) Chemical treatment

- **Added Lime and Soda ash with water to remove Magnesium And Calcium salts**

UNIT - II

DIESEL, GAS TURBINE

&

COMBINED CYCLE

- **Isentropic process** only work transfer no heat transfer.

- An **adiabatic process** occurs without transfer of heat or mass of substances between a thermodynamic system and its surroundings

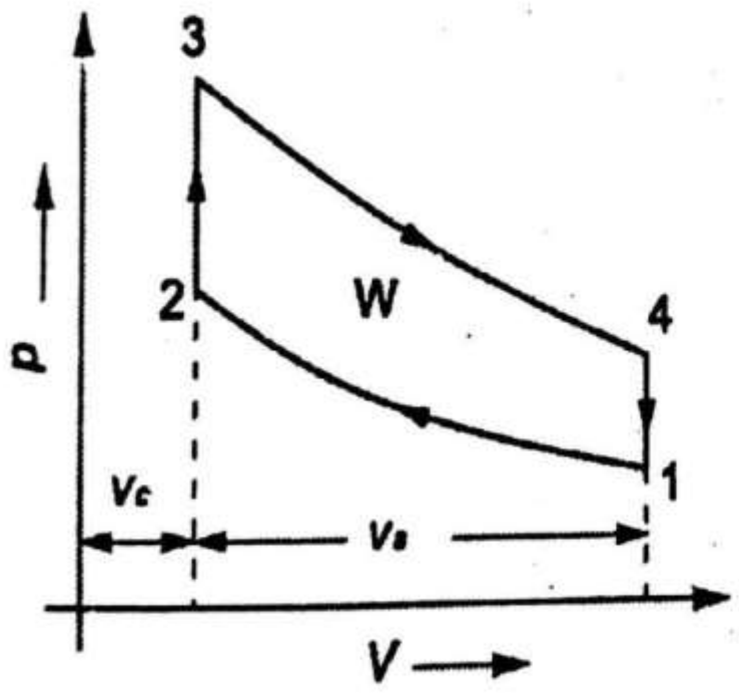
- **T-s diagram** is the type of **diagram** most frequently used to analyze energy transfer system cycles

- **Entropy** is a measure of disorder or randomness of a system. An ordered system has *low* entropy. A disordered system has *high* entropy.

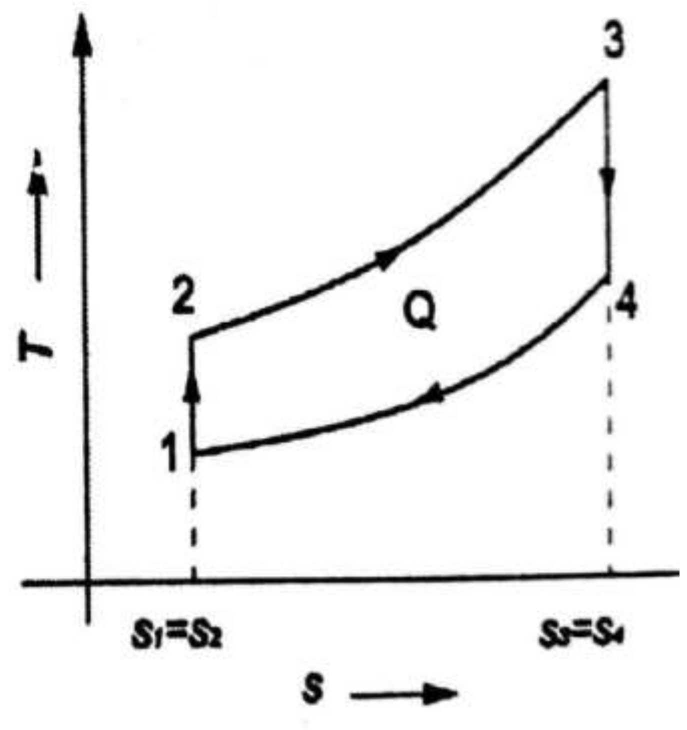
- **Enthalpy** is defined as the sum of internal energy of a system and the product of the pressure and volume of the system.

BASIC CYCLES

1) OTTO CYCLE



p-V diagram



T-s diagram

Process

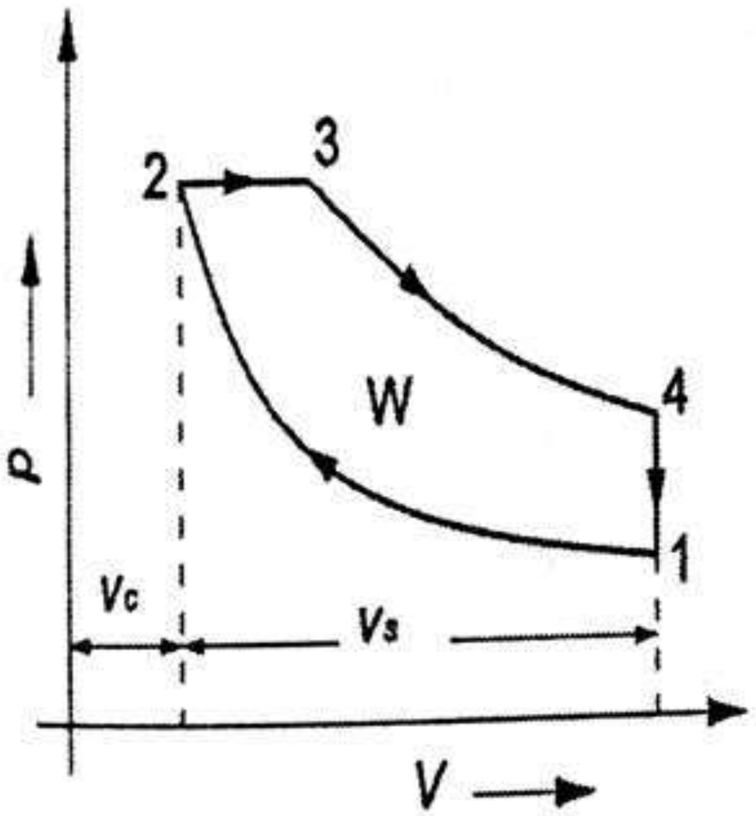
1-2 → Isentropic Compression process

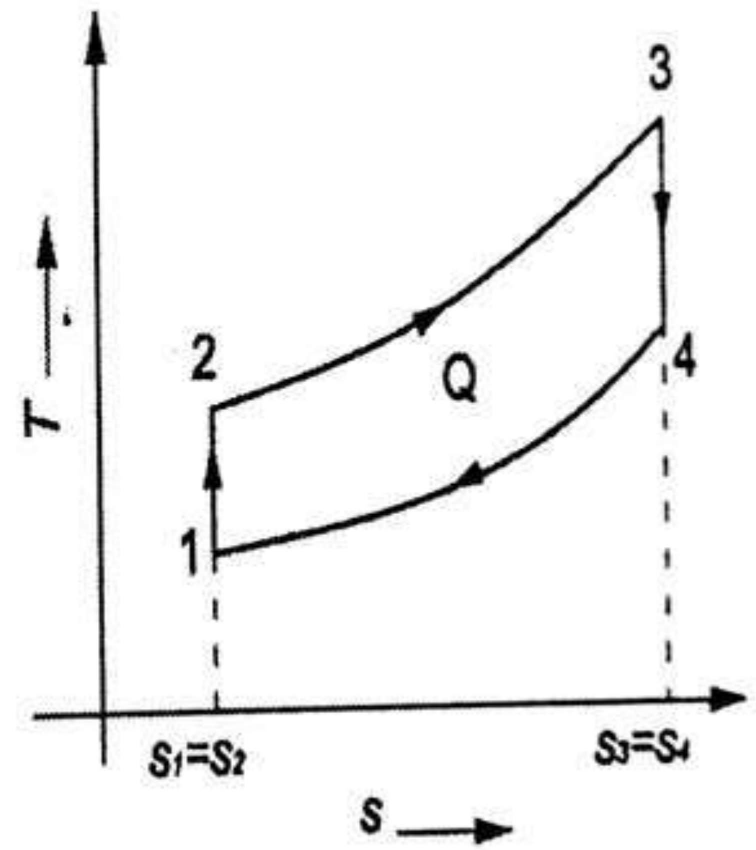
2-3 → Constant Volume heat addition Process

3-4 → Isentropic Expansion process

4-1 → Constant Volume heat rejection Process

2) DIESEL CYCLE





Process

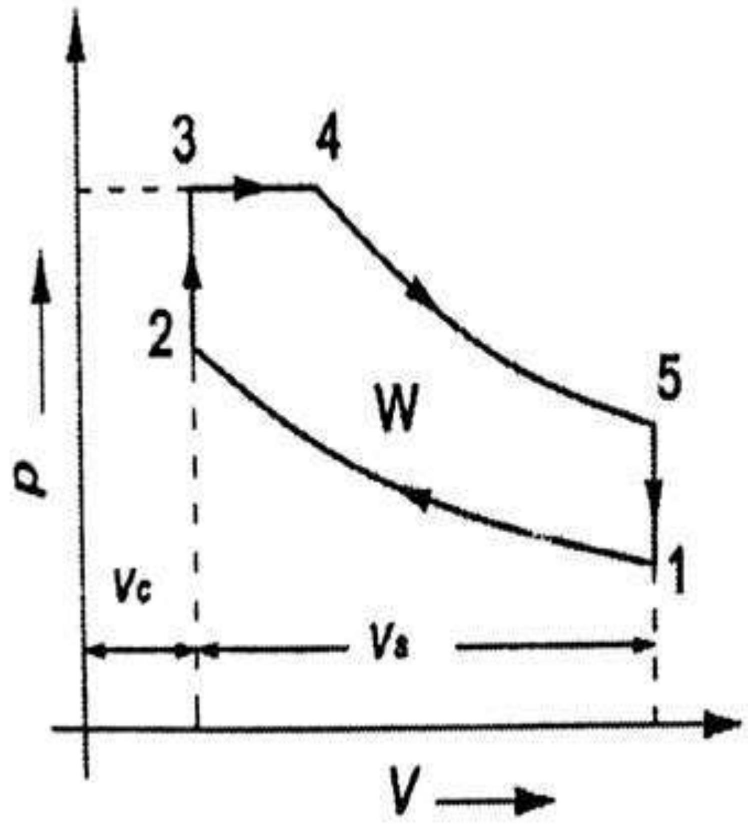
1-2 → Isentropic Compression process

2-3 → Constant Pressure heat addition Process

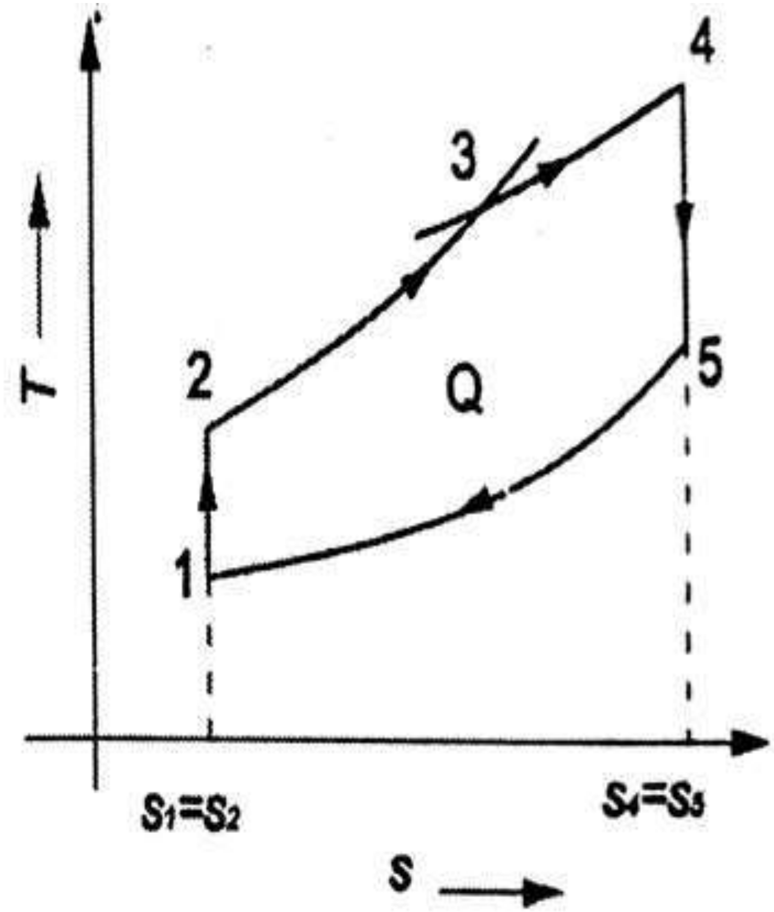
3-4 → Isentropic Expansion process

4-1 → Constant Volume heat rejection Process

3) DUAL CYCLE



p-V diagram



T-s diagram

Process

1-2 → Isentropic Compression process

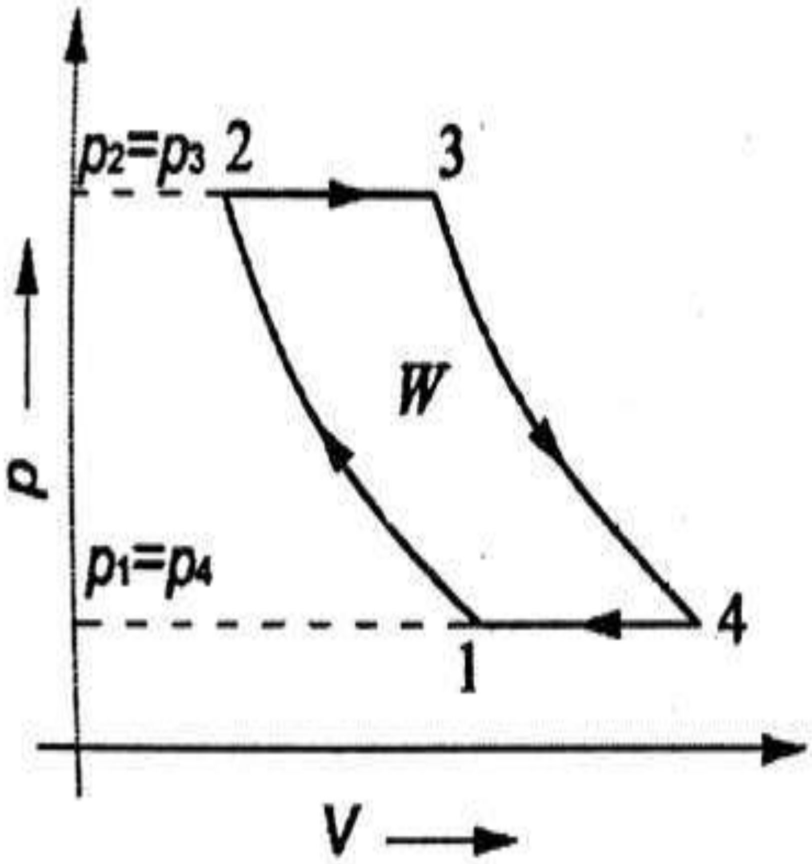
2-3 → Constant Volume Heat addition Process

3-4 → Constant Pressure Heat addition Process

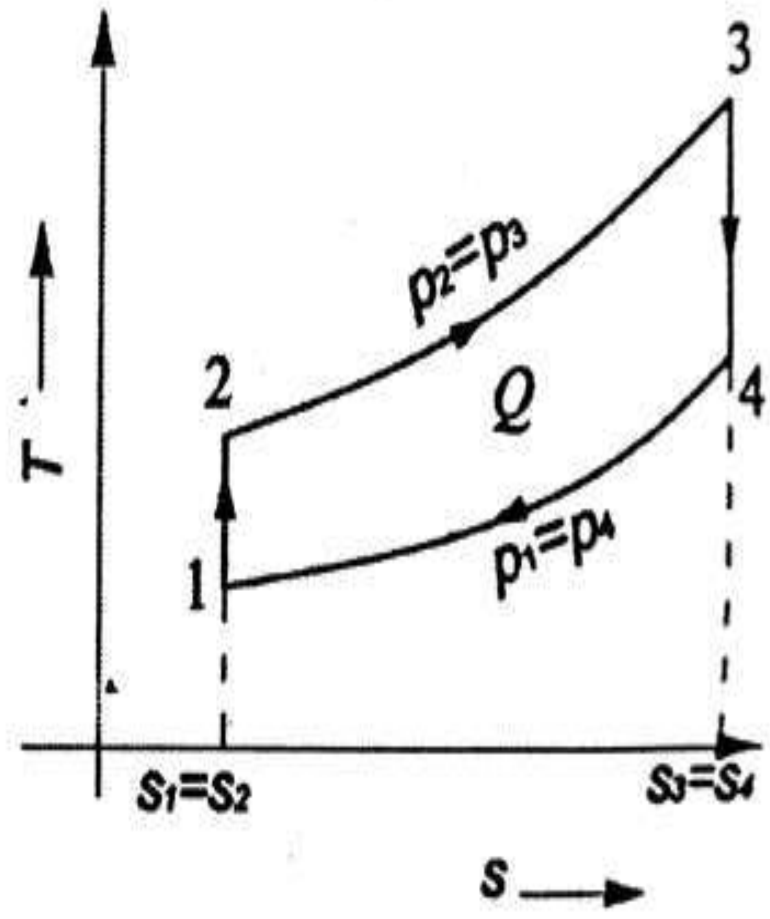
4-5 → Isentropic Expansion process

5-1 → Constant Volume heat rejection process

4) BRAYTON CYCLE



p-V diagram



T-s diagram

Process

1-2 → **Isentropic Compression process**

2-3 → **Constant Pressure heat addition Process**

3-4 → **Isentropic Expansion process**

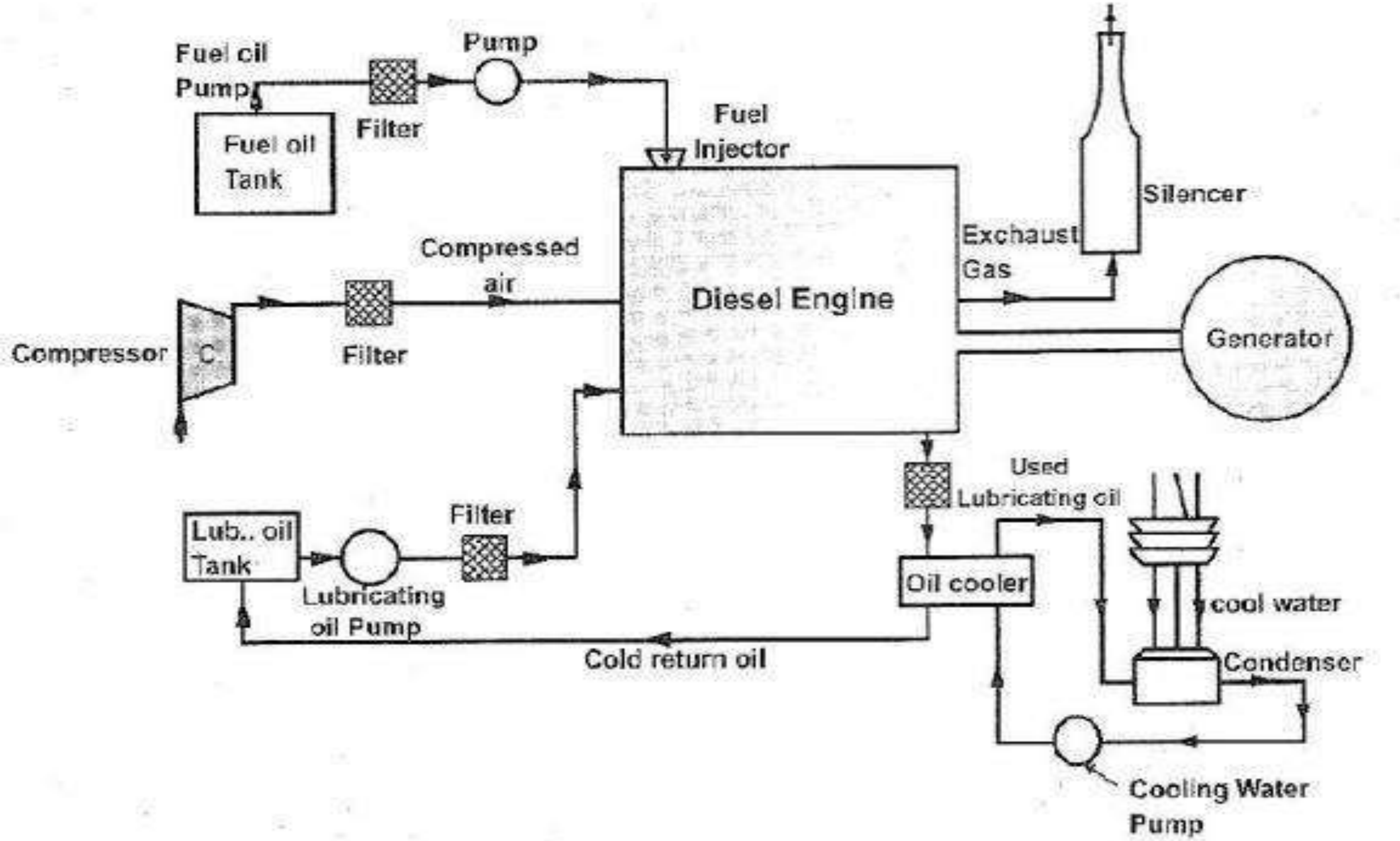
4-1 → **Constant Pressure heat rejection Process**

Diesel Power Plant

Essential components of a diesel power plant

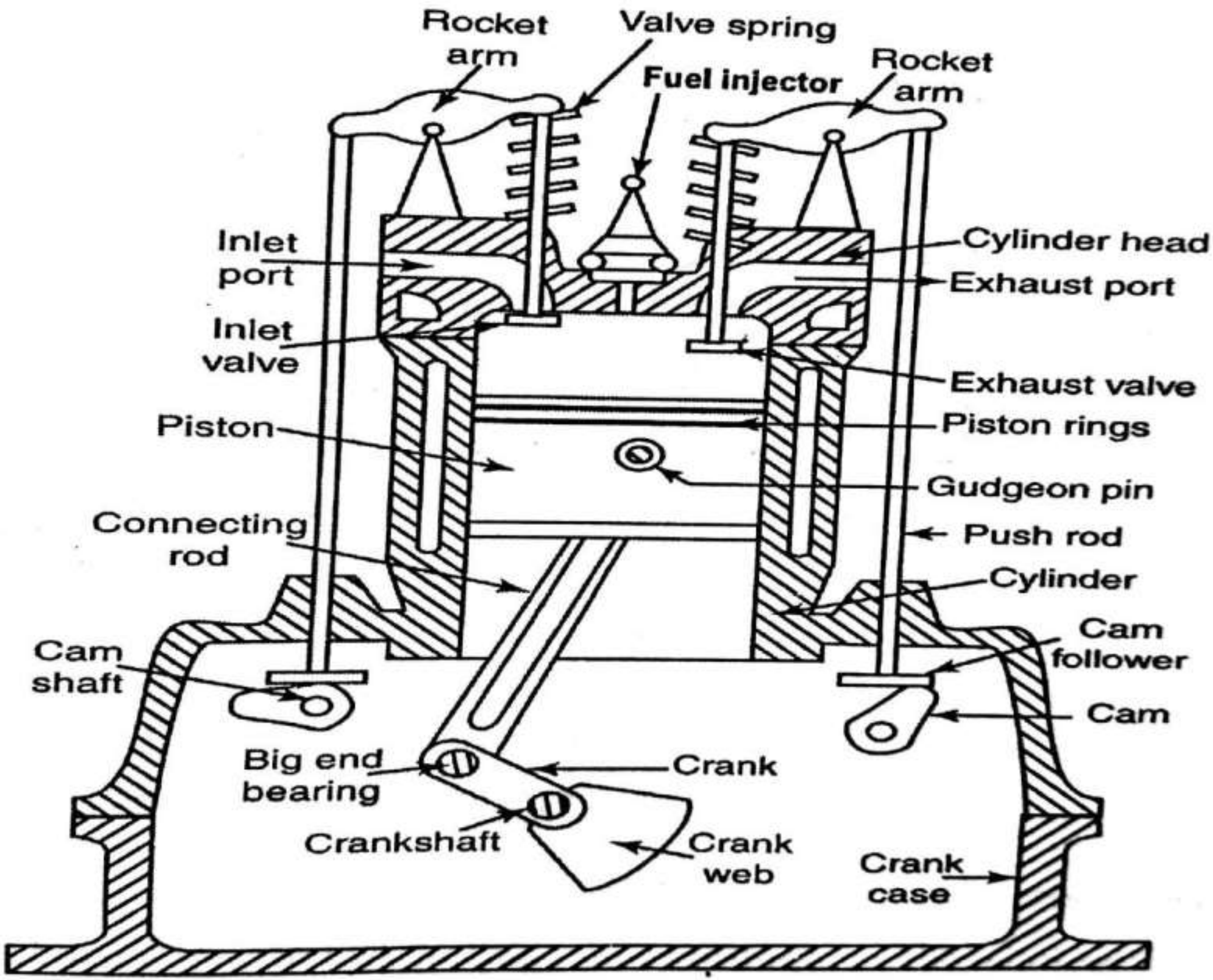
1) Engine
2) Air intake system
3) Engine starting system
4) Fuel system
5) Exhaust system
6) Cooling system
7) Lubrication system

Layout of Diesel Power plant



Major Components of engines are,

1. Cylinder head
2. Piston and cylinder assembly
3. Piston rings
4. Cam shaft
5. Crank shaft
6. Connecting rod
7. Crank case
8. Fuel Injector and FIP
9. Inlet and Exhaust valves
10. Push rod



Rocket arm
Valve spring
Fuel injector
Rocket arm
Inlet port
Cylinder head
Exhaust port
Inlet valve
Exhaust valve
Piston
Piston rings
Gudgeon pin
Connecting rod
Push rod
Cylinder
Cam shaft
Cam follower
Cam
Big end bearing
Crank
Crankshaft
Crank web
Crank case

Cooling System

Need of cooling system

1. To reduce the engine temperature.
2. To increase the engine life.

Types of cooling system

3. Air cooling
4. Water cooling
    a) Thermo-syphon cooling
    b) Pump circulation cooling
5. Liquid cooling

Thermo-syphon Cooling System

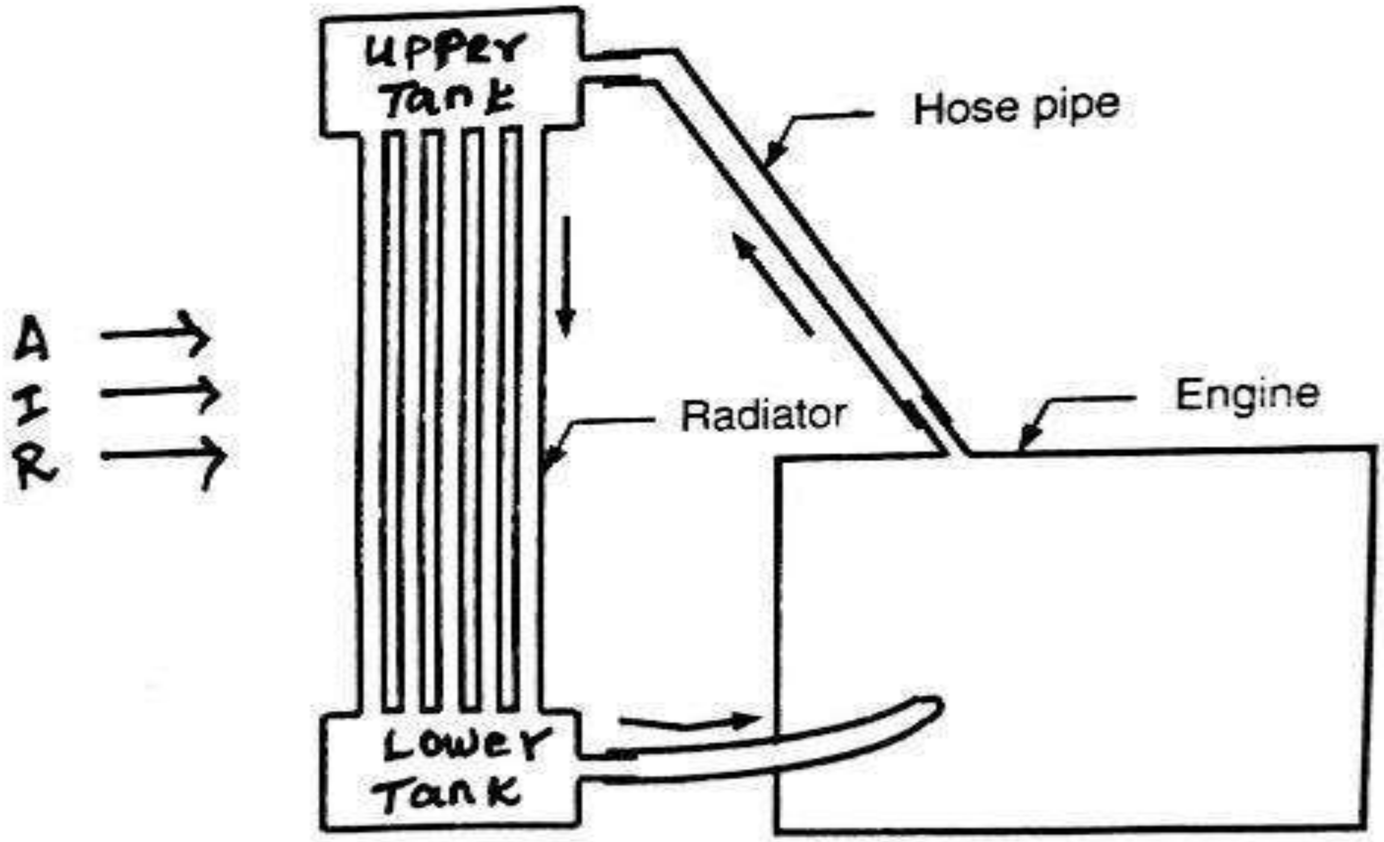


Figure 2.58 Thermosyphon system of cooling

Pump Circulation Cooling System

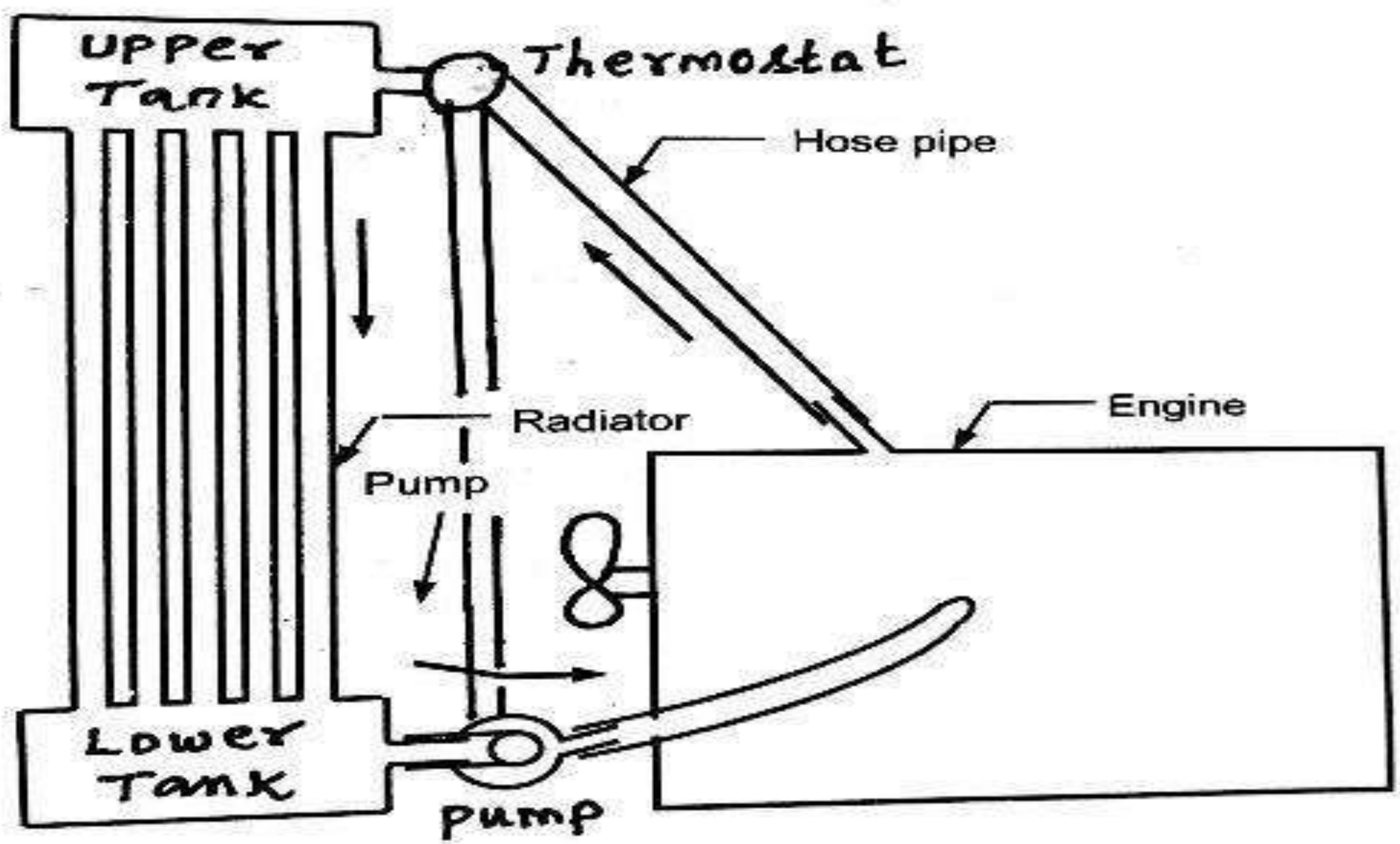


Figure 2.59 Pump circulation system

Lubrication System

Functions of lubrication

a) It reduces friction between moving parts.

b)It reduces wear and tear of the moving parts.

c) It minimizes power Loss due to friction.

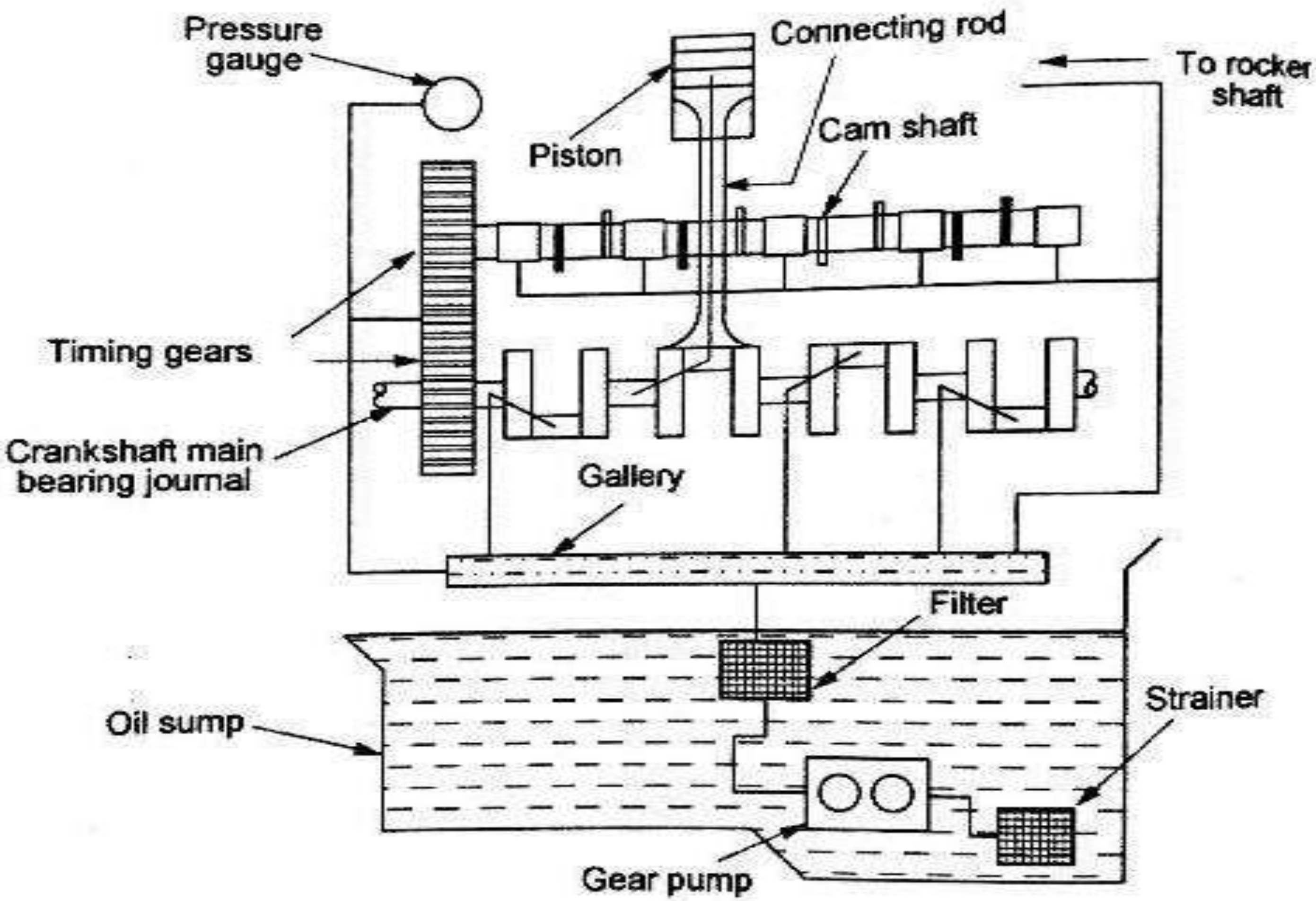
d) It reduce the heat.

e) It reduce the noise.

Types of lubrication system,

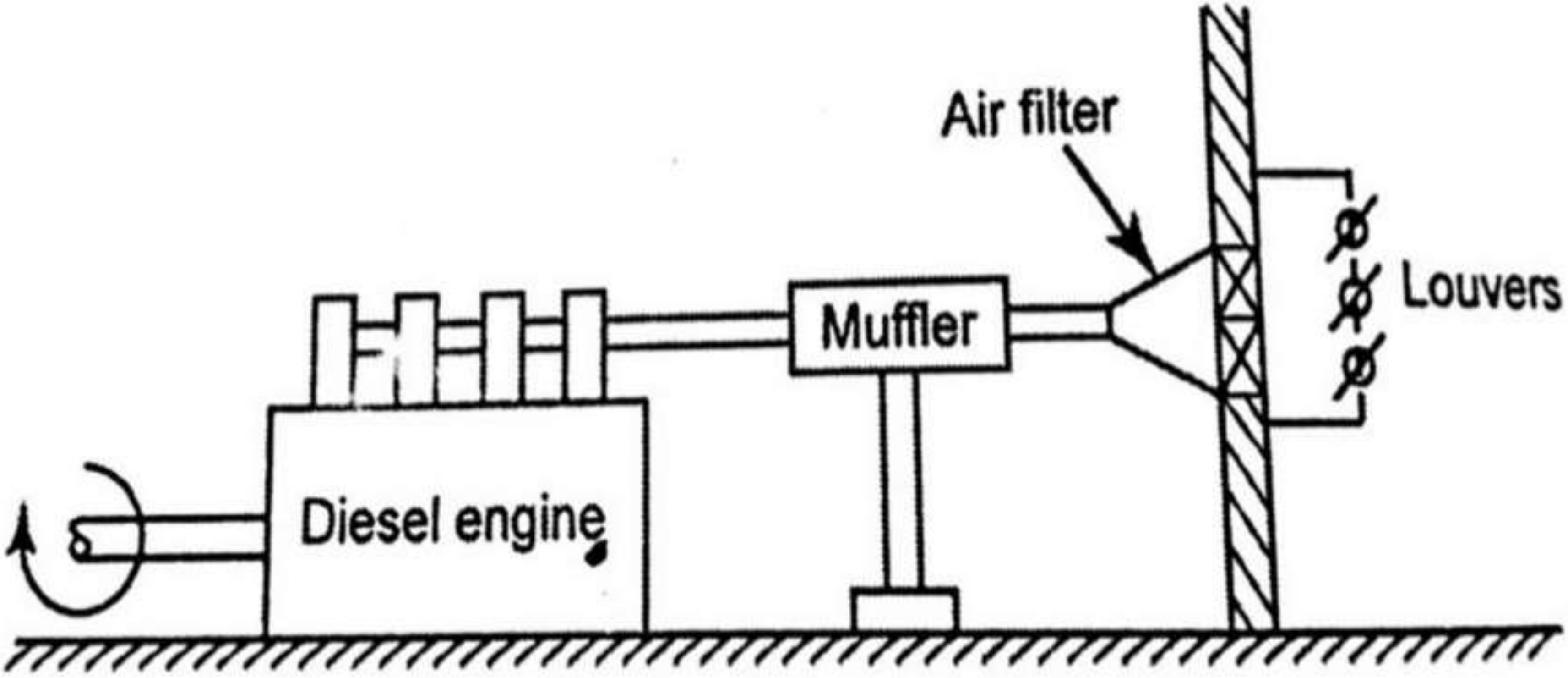
1. Petrol (or) Mist Lubrication system.
2. Wet sump system.
    a) Splash lubrication system
    b) Gravity lubrication system
    c) Pressure lubrication system
    d) Semi-pressure lubrication system.
3. Dry sump system.

Pressure Lubrication System

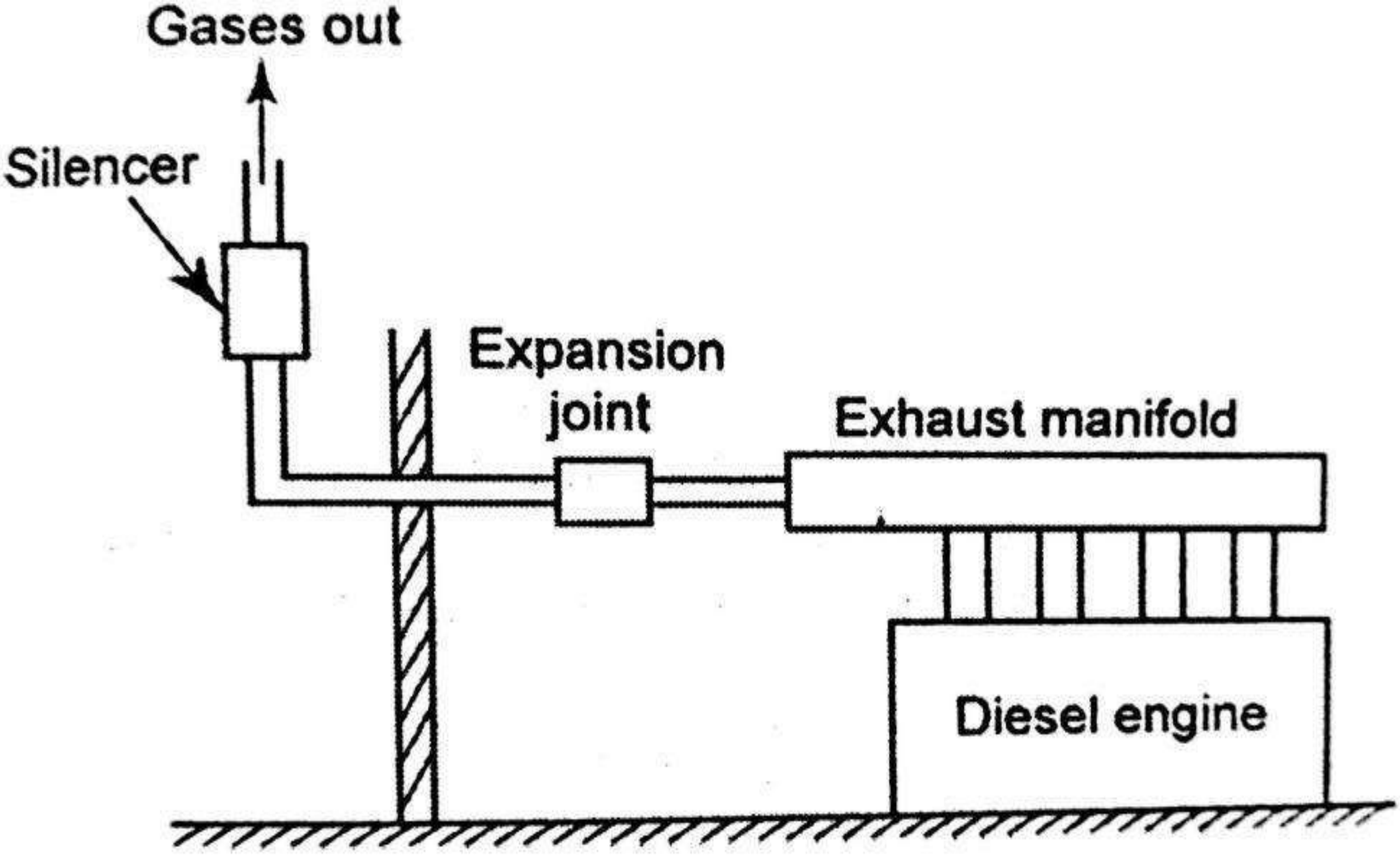


Lubrication System

Air Intake System



Exhaust system



Engine starting system

1) Starting by an auxiliary engine

2) Use of electric motors (or) Self starters

3) Compressed air system

Merits Of Diesel Power Plant

1. Diesel power plant is cheaper.
2. The plant layout is simple.
3. The location of the plant is near the load centre.
4. Skilled man power is not required.
5. It provides quick starting
6. Fuel handling is easy.
7. It occupies less space.
8. Design and installation are very simple.

Demerits Of Diesel Power Plant

1. The repair cost and maintenance cost are high.
2. The plant capacity is limited to about 50MW of power
3. The life of the diesel power plant is low
4. Diesel fuel is much more expensive.
5. The efficiency of the Diesel engine is about 33% only.

Application Of Diesel Power Plant

- **Peak load plant**
- **Mobile plants**
- **Stand by units**
- **Emergency plant**
- **Starting station**
- **Nursery station**

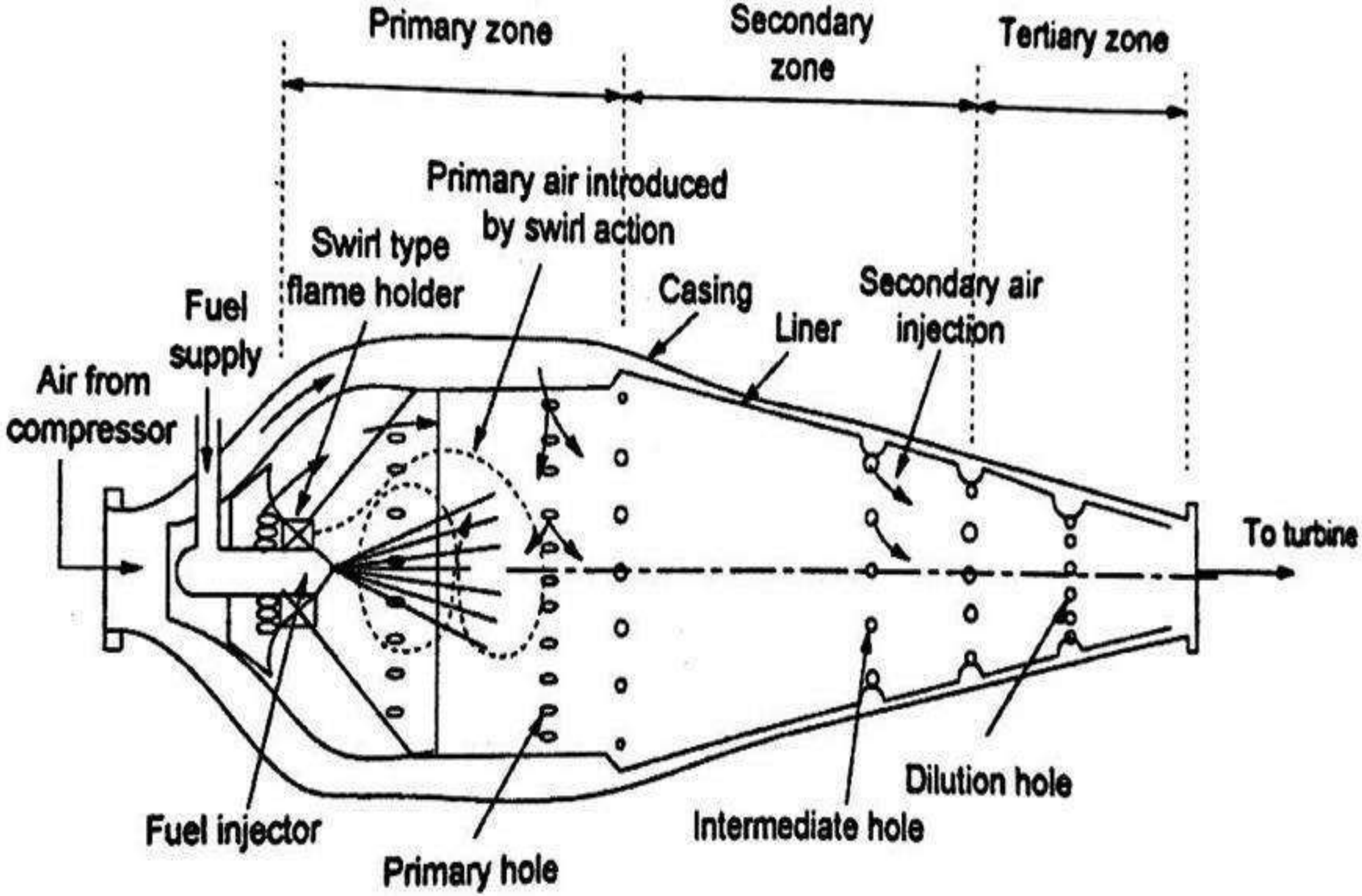
Selection Of Diesel Engine

- **Amount of fuel burned per minute**
- **Fuel Injection system**
- **Combustion processes**
- **Fuel-Air ratio**
- **Type of engine**
- **Cooling method**
- **Size of cylinder**
- **Volumetric efficiency**
- **Specific weight**

Essential Components Of A Gas Turbine

Components are,

1. **Compressor**
2. **Combustion chamber**
3. **Turbine**


Primary zone
Secondary zone
Tertiary zone
Primary air introduced by swirl action
Swirl type flame holder
Fuel supply
Air from compressor
Casing
Liner
Secondary air injection
To turbine
Fuel injector
Primary hole
Intermediate hole
Dilution hole

Construction details of combustion chamber:

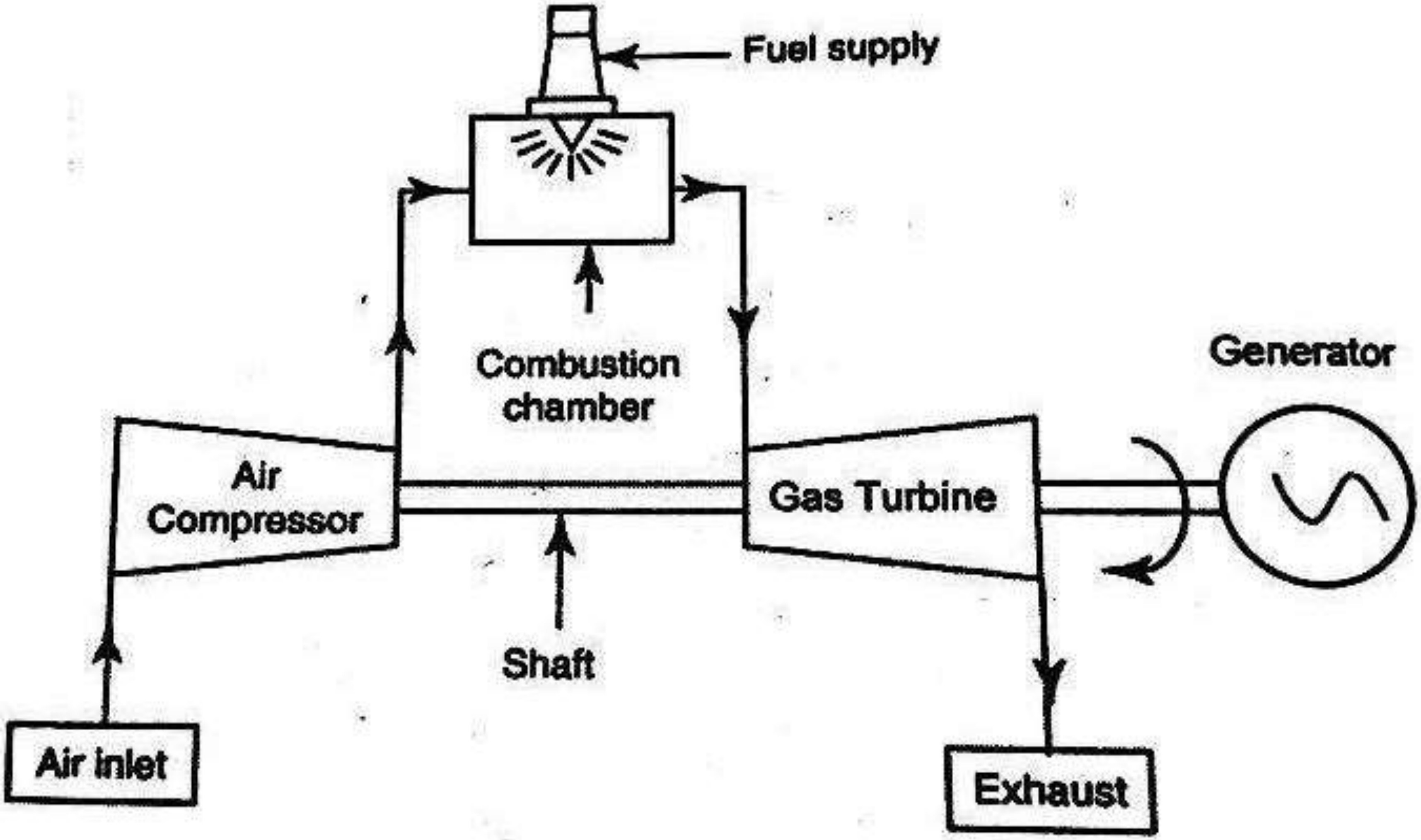
1. Case
2. Diffuser
3. Liner
4. Snout
5. Dome and Swirler
6. Fuel injector

Types Of Gas Power Plant

According to the cycle of operation it is classified into two types,

1) **Open cycle gas power plant**
2) **Closed cycle gas power plant.**

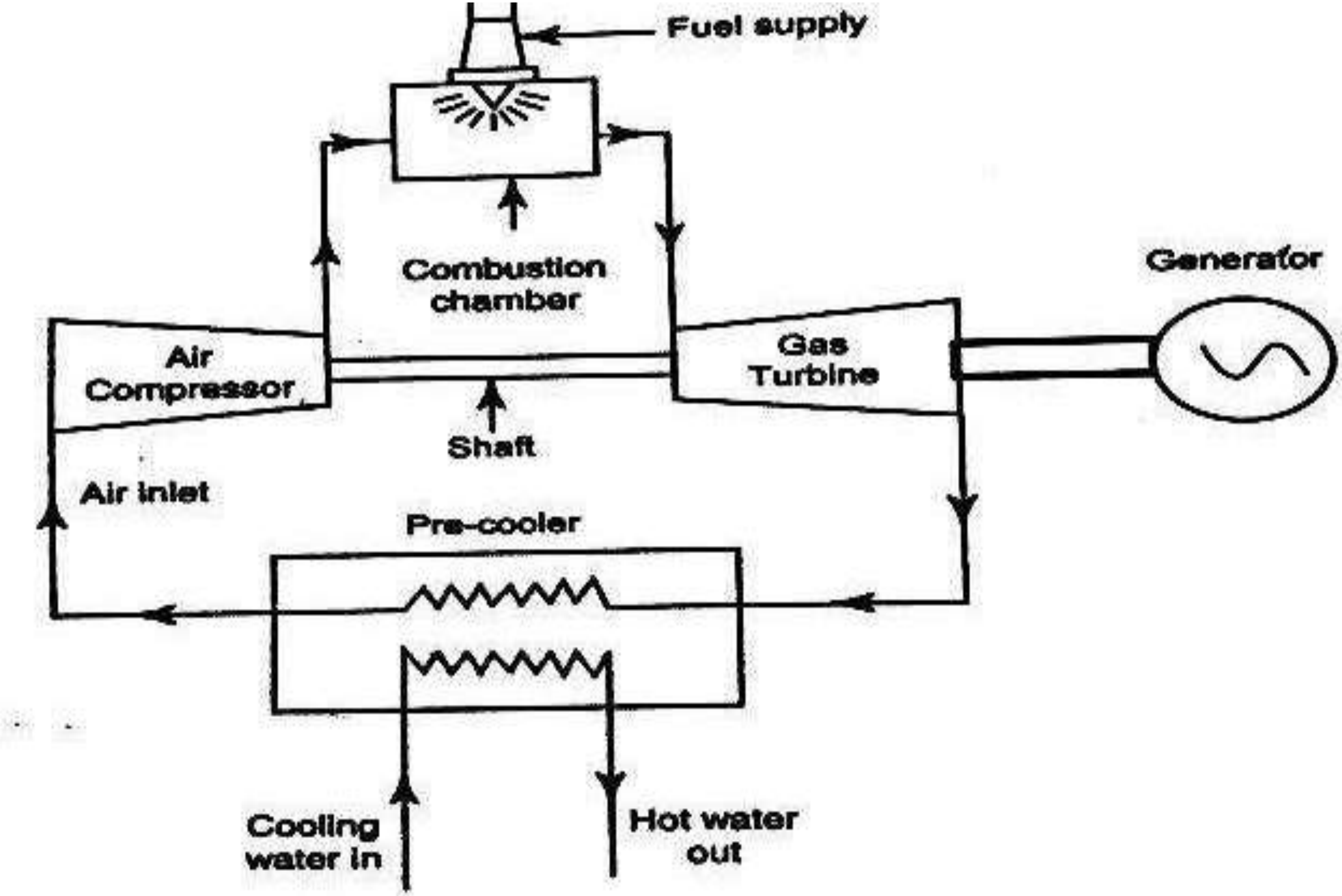
Open cycle gas power plant



Components are,

1. **Air compressor**
2. **Combustion chamber**
3. **Gas turbine**
4. **Generator**

Closed cycle gas power plant



Components are,

1. **Air compressor**
2. **Combustion chamber**
3. **Gas turbine**
4. **Generator**
5. **Pre-cooler**

Advantages of Gas power plants

1) It is smaller in size and weight
2) Natural gas is a very suitable fuel
3) It has less vibration
4) Low initial cost
5) The installation and maintenance costs are low
6) It requires less water
7) It can be started quickly.

Disadvantages of Gas power plants

1) Part load efficiency is poor

2)Major part of the work(66%) is used to drive the compressor

3)The devices that are operated at high temperature are complicated

Application

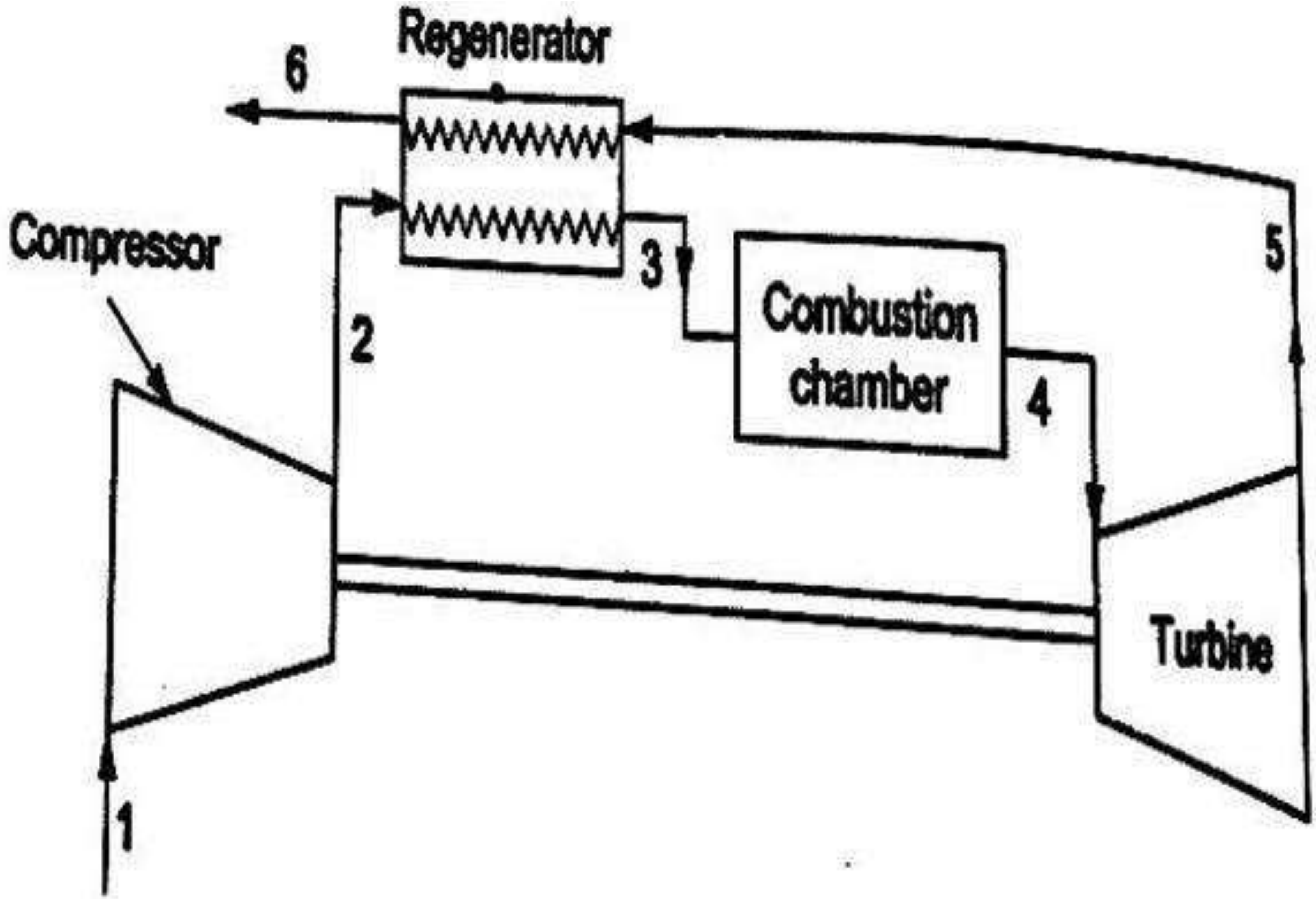
- **They are mainly used as Peak load power station,**
- **Emergency stand-by unit**
- **Hydrostatic stand-by unit.**
- **Base load power plants.**
- **The quick starting and good response characteristics**

Improvement Of Gas Power Plant

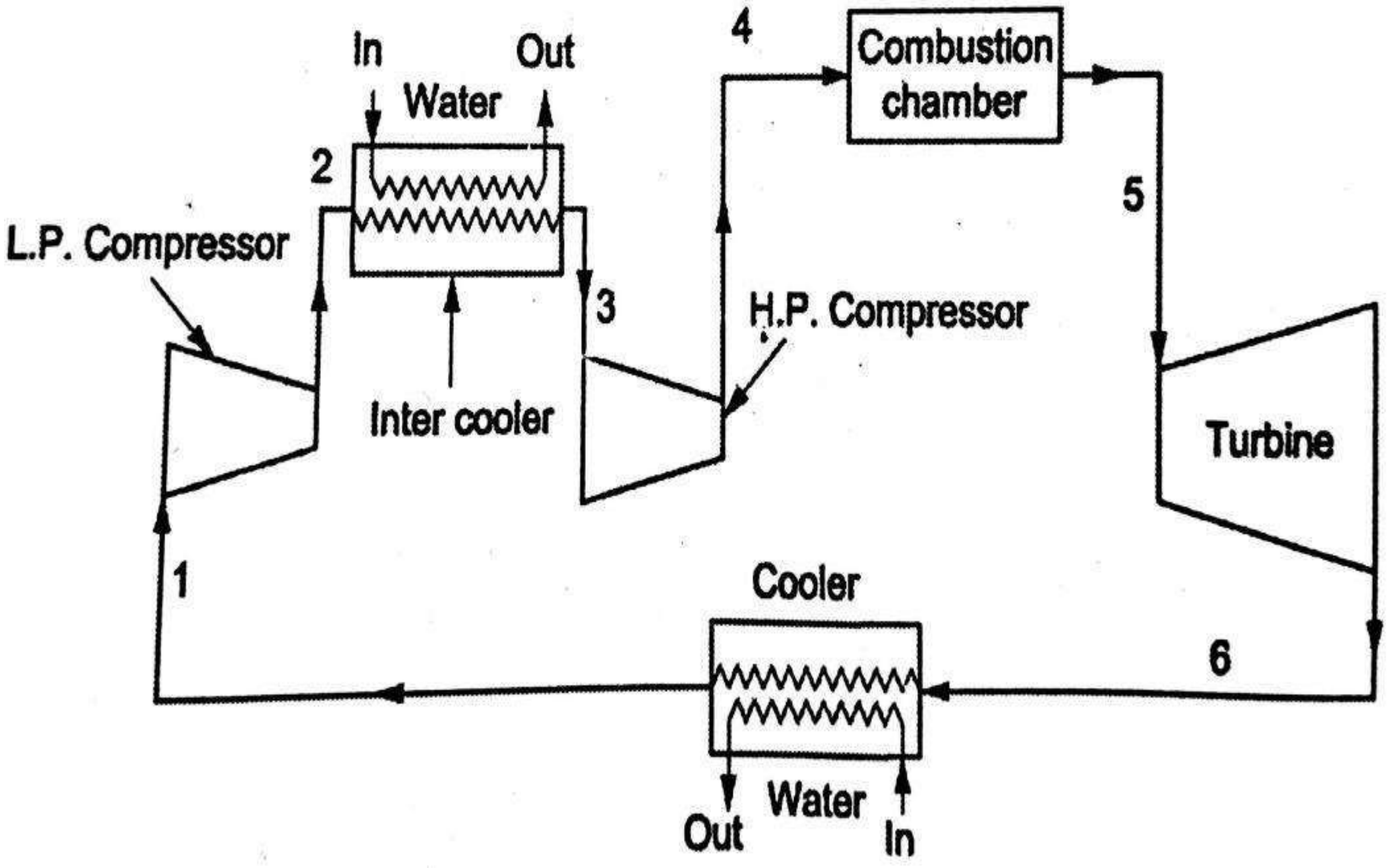
The efficiency of gas turbine power plants can be improved in four ways,

1. **Regenerator**
2. **Intercooler**
3. **Re-heater**
4. **Combined regenerator, Intercooler and re-heater**

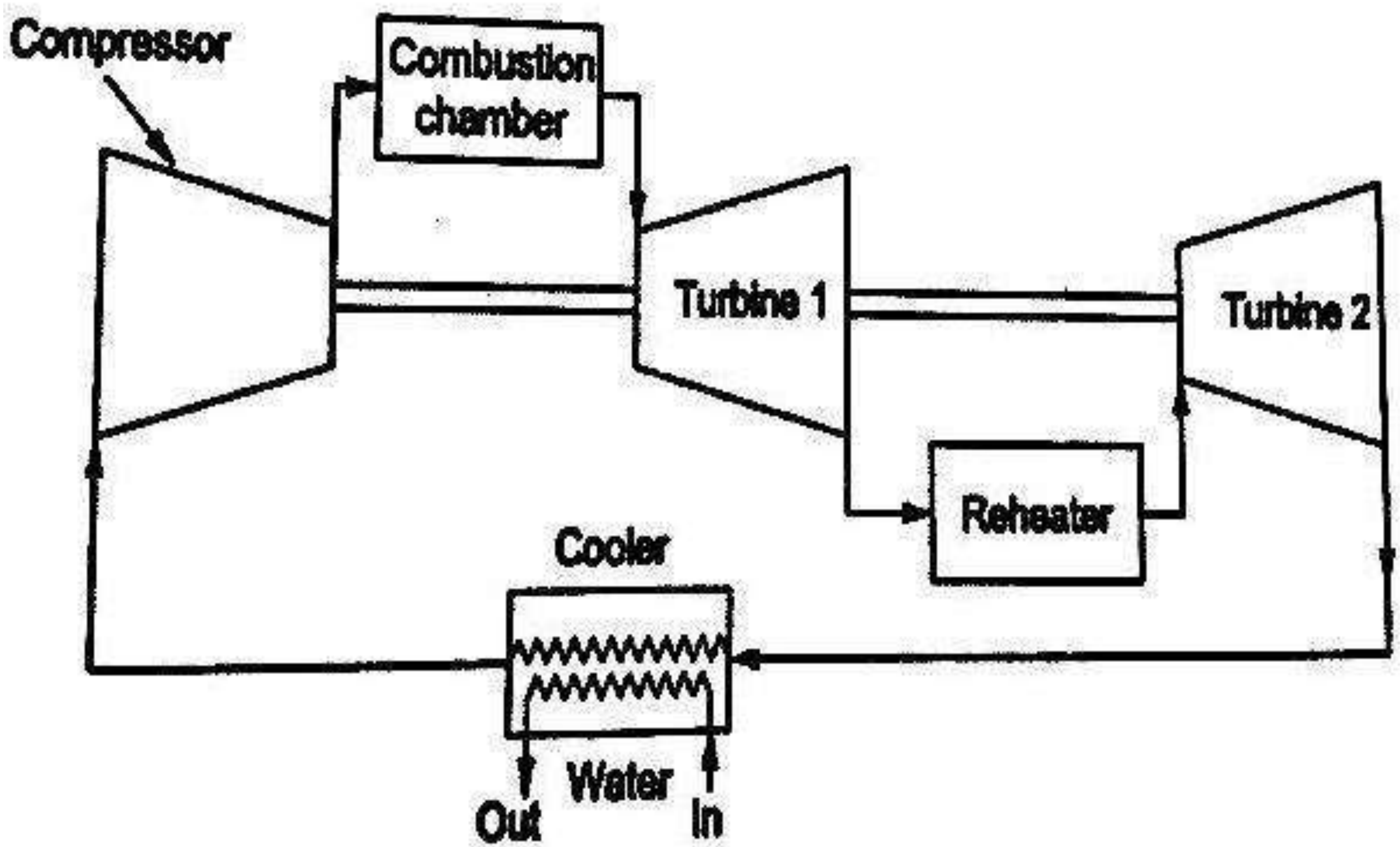
Regenerator



Intercooler



Re-heater



Compressor
Combustion chamber
Turbine 1
Turbine 2
Reheater
Cooler
Water
Out
In

Combined Power Plant

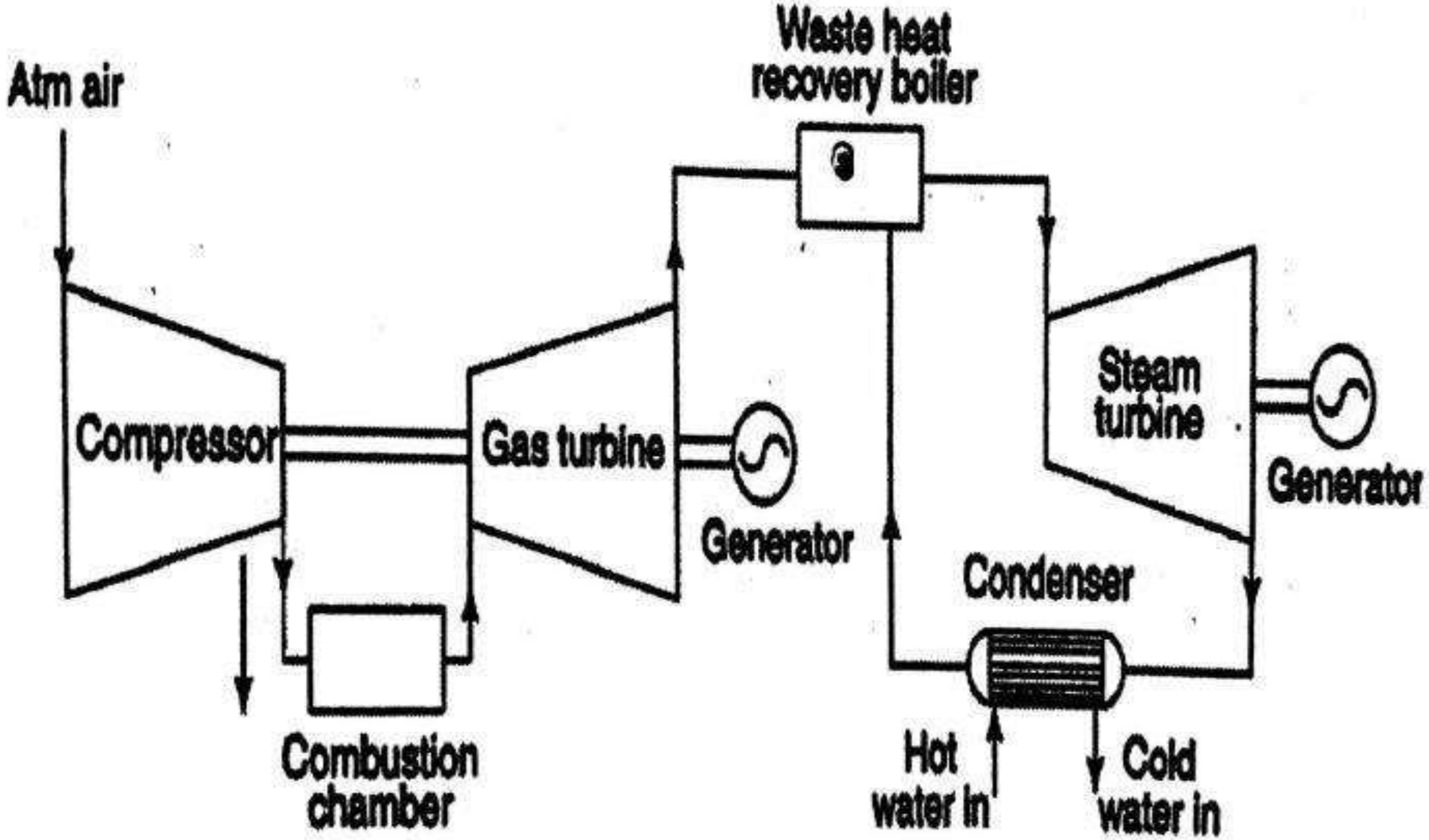
Combined Power Plant

- **The maximum steam temperature in a power cycle exceeds 600 C but the pulverized coal furnace temperature is about 1300 C.**
- **So, there is a lot of energy wasted in the power plant.**
- **To increase the efficiency and reduce the fuel consumption, the combined power cycles are introduced.**

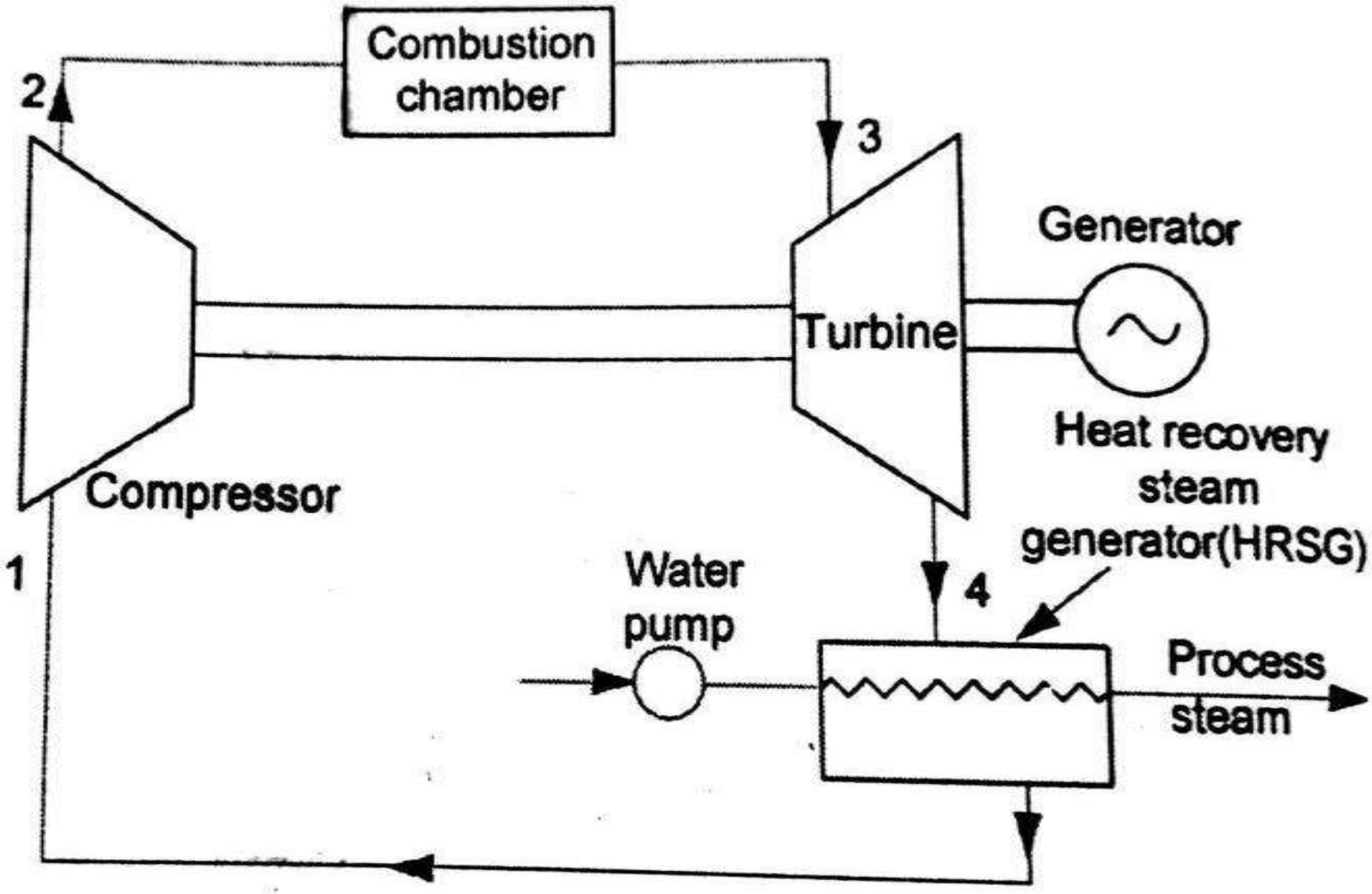
Types of combined power cycle:

1. **Gas turbine – Steam turbine power plant.**
2. **Combined gas turbine and co-generation power plant**
3. **Combined gas turbine and diesel power plant**
4. **Nuclear – Steam combined power plant.**

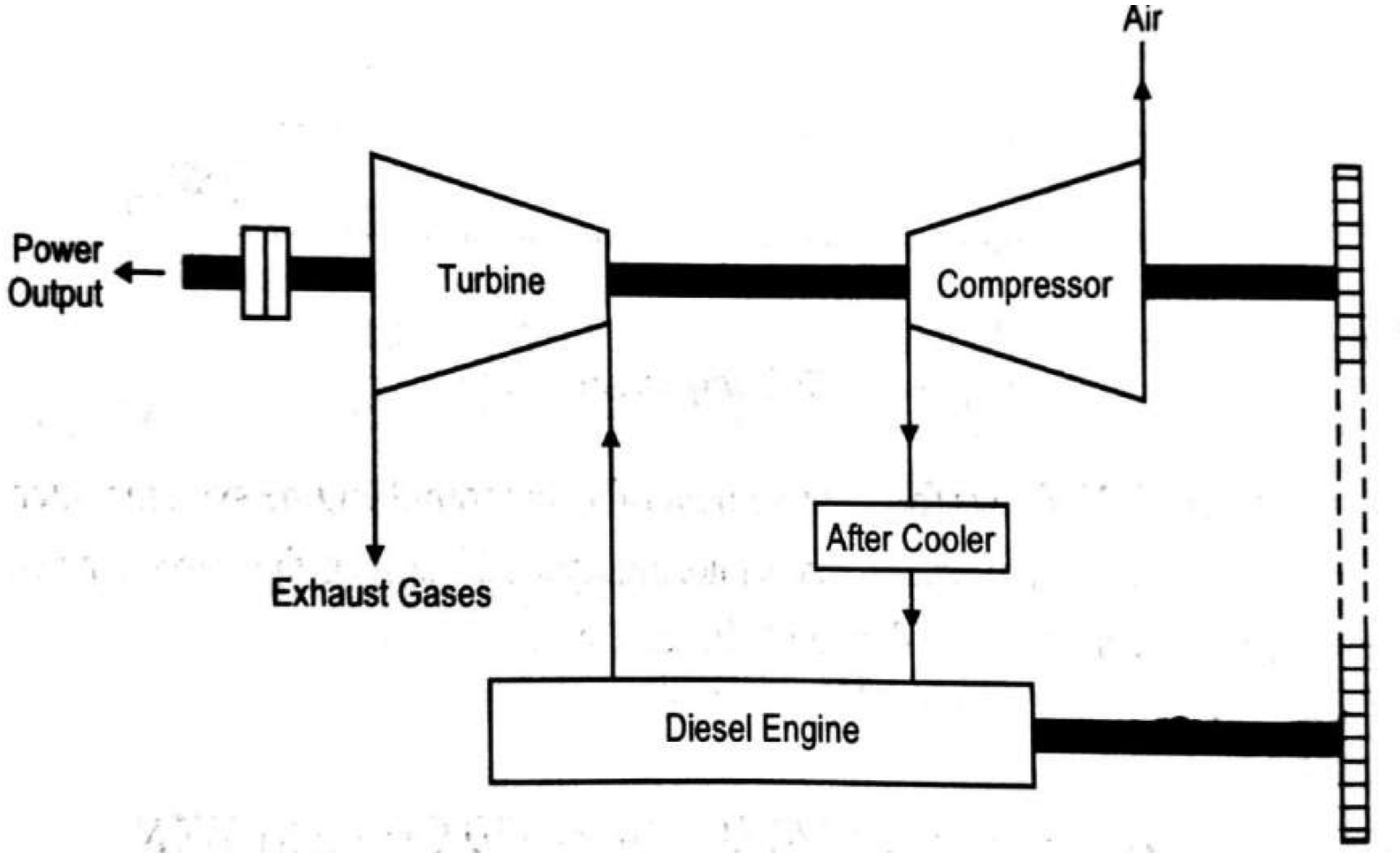
1) Gas Turbine – Steam Turbine Power Plant



2) Combined Gas Turbine And Co-generation Power Plant



3) Combined gas turbine and diesel power plant



Integrated Gasification Combined Cycle (IGCC)

IGCC plant consists of the following four major units:

1. Air separation Unit (ASU)

ASU supplies Oxygen and steam required for gasification

2. Gasification system

The unit has a coal Gasifier where the conversion of solid fuel into combustible syngas takes Place.

3. Gas clean-up

It filters the impurities in syngas

4. Combined power block

It consists of a steam turbine and gas turbine for power production.

IAE – I

1) Layout of thermal power plant

2)High pressure boiler(La-Mont, Benson, Loeffler and Velox)

3)Super critical boiler(Drum type, once through boiler)

4) Fluidized Bed Combustion(FBC)

5) Fluidized Bed Boilers(BFB & CFB)

6) Ash handling system

7) Coal handling system

8) Surface condenser

9) Types of stokers

10) Draught systems

11) Types of Co-generation

12) Binary cycle

13) Cyclone separator, Electro static precipitator (ESP)

14) Types of cooling tower(Hyperbolic cooling tower)

15) Feed water treatment

UNIT- II

1) PV & TS diagram and process
2) Layout of diesel power plant
3) Air intake system & Exhaust system
4) Main components of Gas power plant
5) Types of gas power plant
6) Types of combined power plants
7) How to improve the efficiency of Gas power plant(Regenerator, Re-heater & Intercooler)
8) Integrated Gasification Combined Cycle(IGCC)

UNIT- III

NUCLEAR POWER PLANTS

S.NO	FUEL	Percentage
1	Petroleum	39%
2	Natural gas	24%
3	Coal	22%
4	Hydro power	6.9%
5	Nuclear	6.3%

Indian Nuclear Power Plants

Power station	Operator	Establish ment Date	Location	District	State	Reactor Units (MW) (including under constructio)	Installed Capacity (MW)
Tarapur Atomic Power Station	NPCIL	October 28, 1969	Tarapur	Thane	Maharash tra	2 x 160, 2 x 540	1,400
Kakrapar Atomic Power Station	NPCIL	May 6, 1993	Kakrapar	Surat	Gujarat	2 x 220, 2 x 700	440
Western					2	8	1,840

Kudankulam Nuclear Power Plant	NPCIL	October 22, 2013	Kudankulam	Tirunelveli	Tamil Nadu	4 x 1,000	2,000
Kaiga Nuclear Power Plant	NPCIL	November 16, 2000	Kaiga	Uttara Kannada	Karnataka	4 x 220	880
Madras Atomic Power Station	NPCIL	January 24, 1984	Kalpakkam	Kancheepuram	Tamil Nadu	2 x 220, 1 x 500	440
Southern					3	11	3,320

Elementary Theory

Atomic structure

An element is defined as a substance which cannot be decomposed into the other substance.

The smallest particle of an element which takes a part in chemical reaction is known as ‘Atom’

Atomic number

The number of protons in the nucleus is atomic number, it is denoted by ‘’z’

Mass number

The total number of nucleons in the nucleus is called mass number, it is denoted by ‘’A’

The difference between mass number and atomic number gives the number of neutrons

Isotopes:

Some elements exists in different forms,

The mass number is different but the atomic number is same

Nuclear binding energy:

The energy released at the moment of combination of two nucleons to form nucleus an atom is called binding energy.

It is represented by electron volt (eV)

One electron volt = 1.602×10^{-9} KJ

Atomic mass unit

The ‘’amu” is a unit of mass approximately 1.66 x 10^{-24} kg

Radioactivity

Radioactivity is the phenomenon of spontaneous emission of powerful radiations exhibited by heavy elements.

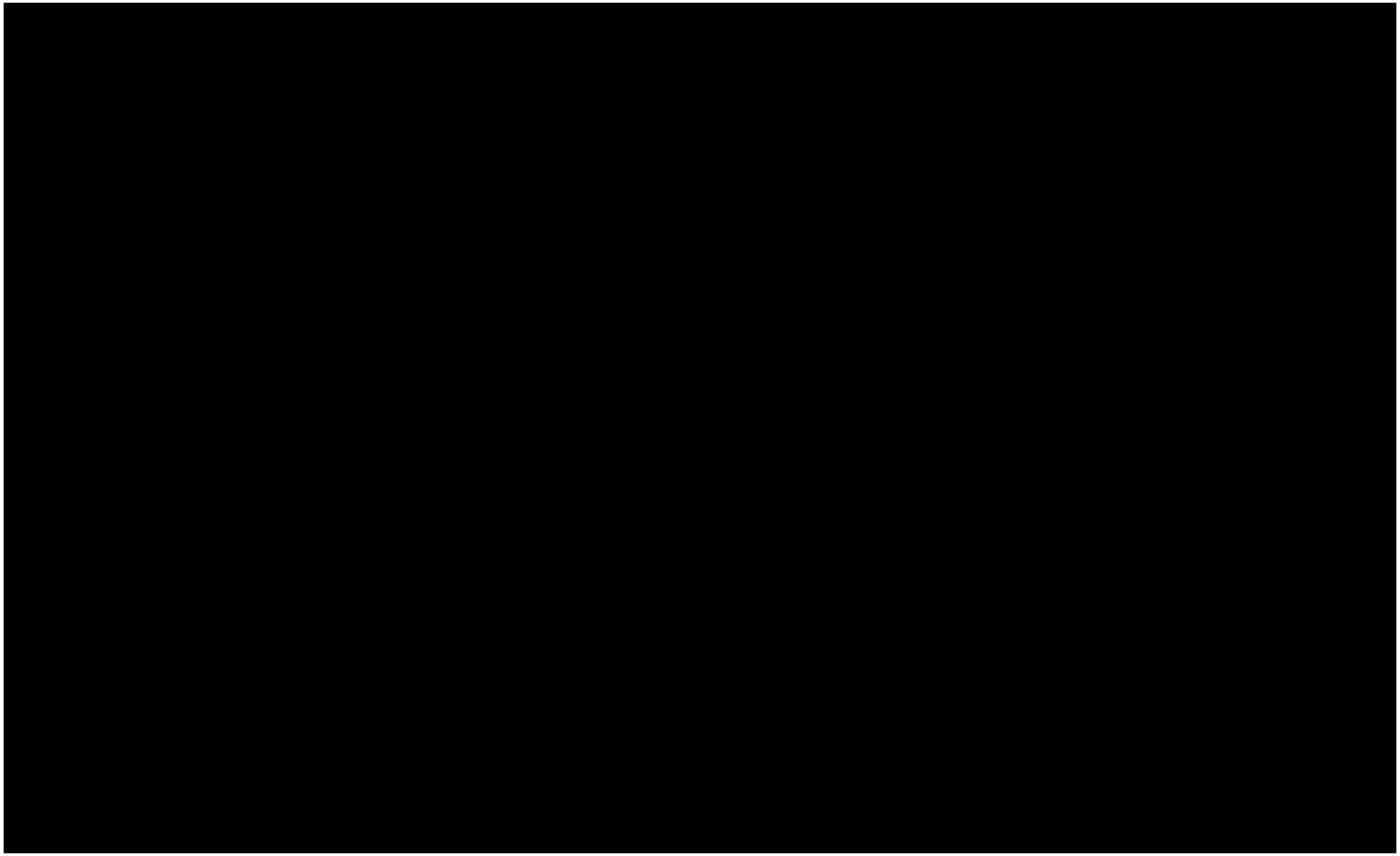
Half -life

The radioactive half-life for a given radioisotope is a measure of tendency of nucleus to ‘’Decay’ and it is purely based on the probability

Name	Half life
Carbon-14	5730 years
Sodium-24	15 Hours
Iron-59	45 Days
Cobalt-60	5.3 years
Uranium-235	710 Million years

Chernobyl disaster

Chernobyl disaster effects



Nuclear Fuels

Fissile fuels:

U^{233} ,U^{235} (Naturel) and PU^{239}

Fertile fuels:

It can be converted to fissionable materials,

PU^{239} ------------------ U^{238}

U^{233} ------------------- Th^{232}

Multiplication factor:

$$K = \frac{\text{Number of neutrons in any particular generation}}{\text{Number of neutrons in the preceding } \textit{generation}}$$

Nuclear Fission:

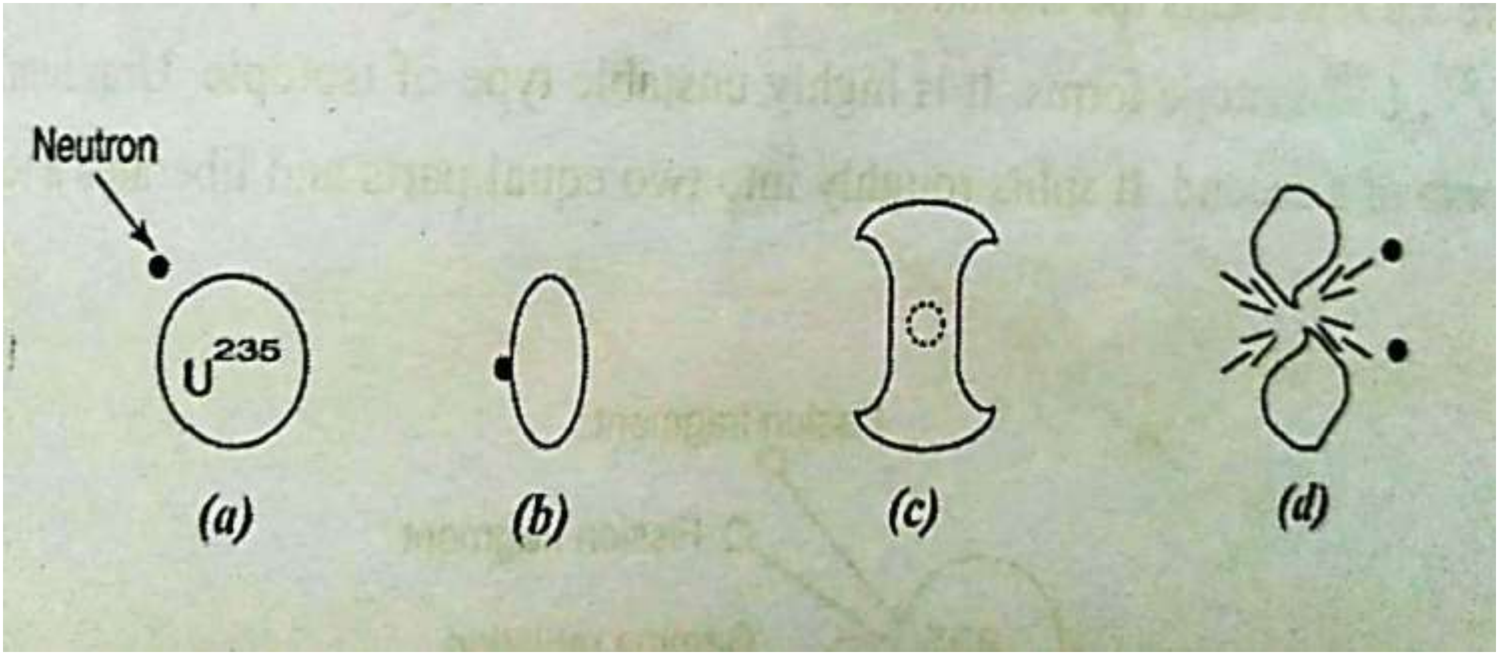
- **It is the process of splitting the unstable heavy nucleus into two fragment of approximately equal mass when bombarded with neutrons.**

a) Pre fission stage

b) Distorted stage

c) Excited stage

d) Post fission stage

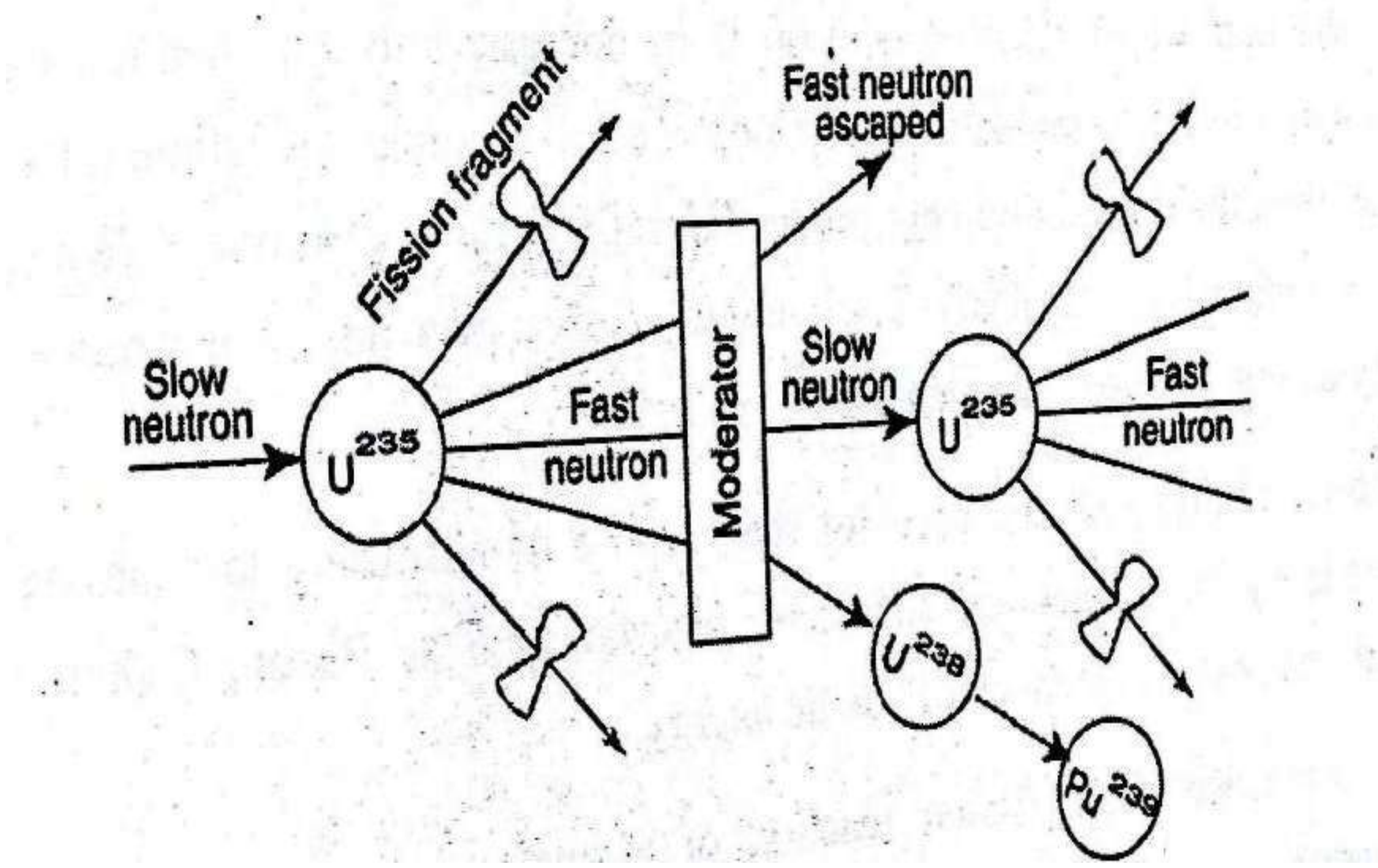


Nuclear Fusion:

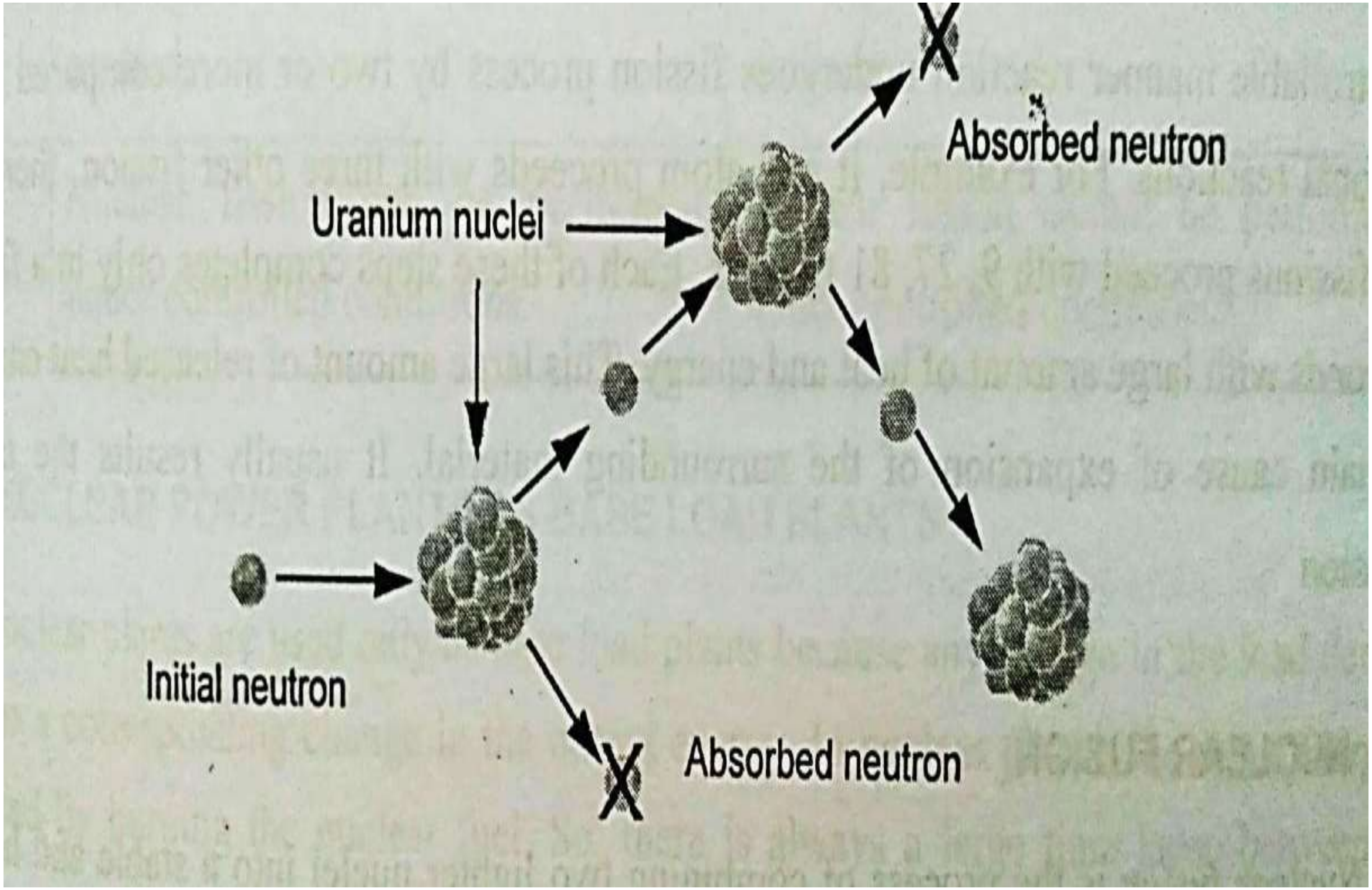
- **Combining or fusing two lighter nuclei into a stable and heavier nucleus. It gives very large amount energy.**
- **This process does not emit any kind of radioactive rays.**
- **This process does not give a rise to chain reaction**

S.no	Fission	Fusion
1.	It is the process of splitting a heavy nucleus with some projectiles into two or more light fragments by liberation of large amount of energy	It is a process of fusing two light nuclei into single nucleus with the liberation of large amount of heat.
2.	This process results the emission of radioactive rays.	Does not emit any kind of radioactive rays.
3.	This process gives a rise to chain reaction	Does not gives a rise to chain reaction
4	Nuclear fission can be controlled conditions.	Nuclear fusion cannot be controlled conditions..

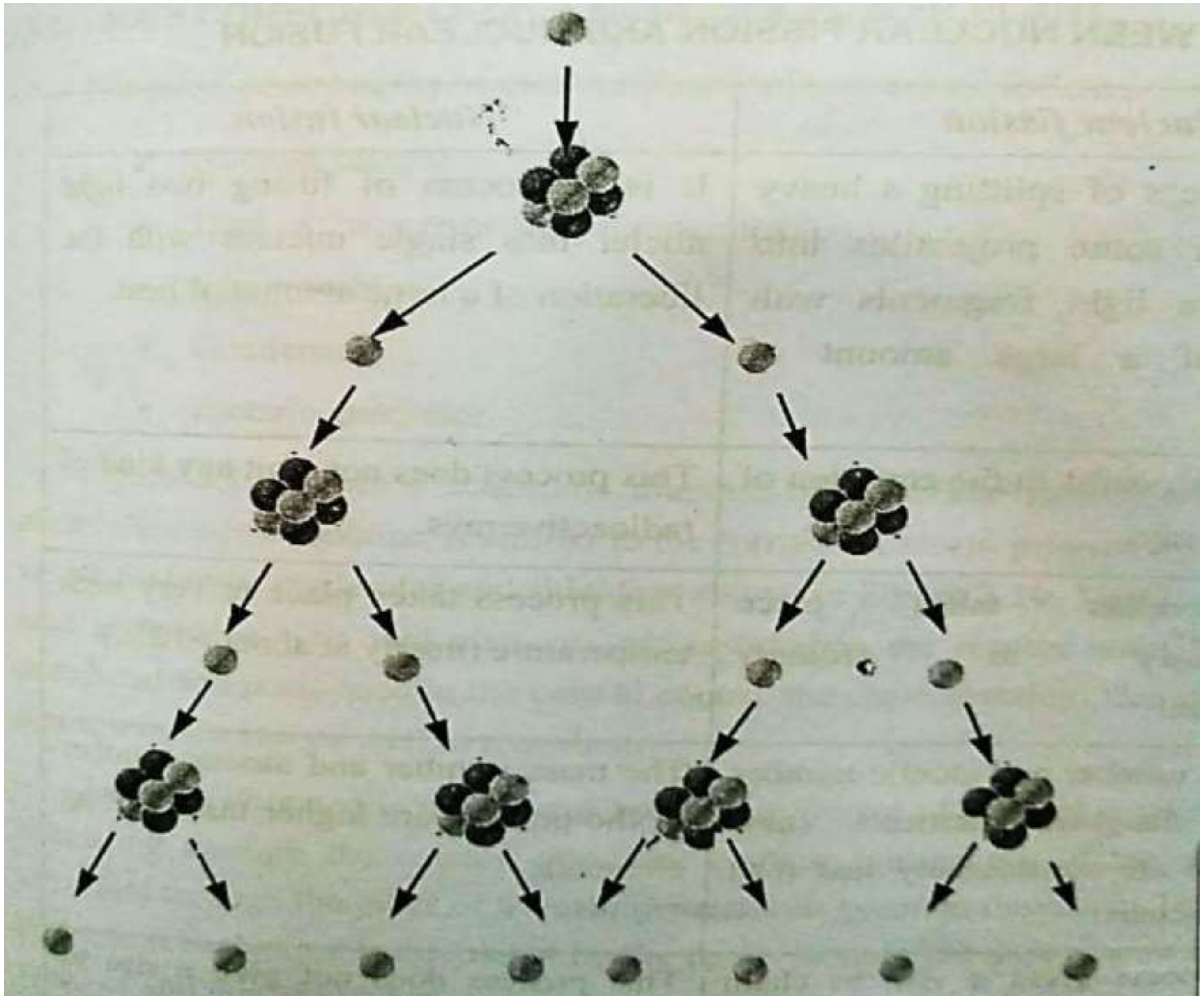
Chain Reaction



Controlled chain reaction



Un controlled chain reaction



- **A chain reaction is that process in which the number of neutrons keeps on multiplying rapidly during fission till, whole of the fissionable material is disintegrated**
- **The chain reaction will become self-sustaining only**

Components Of Nuclear Reactor

1) Reactor Core

2) Moderator

3) Control rod

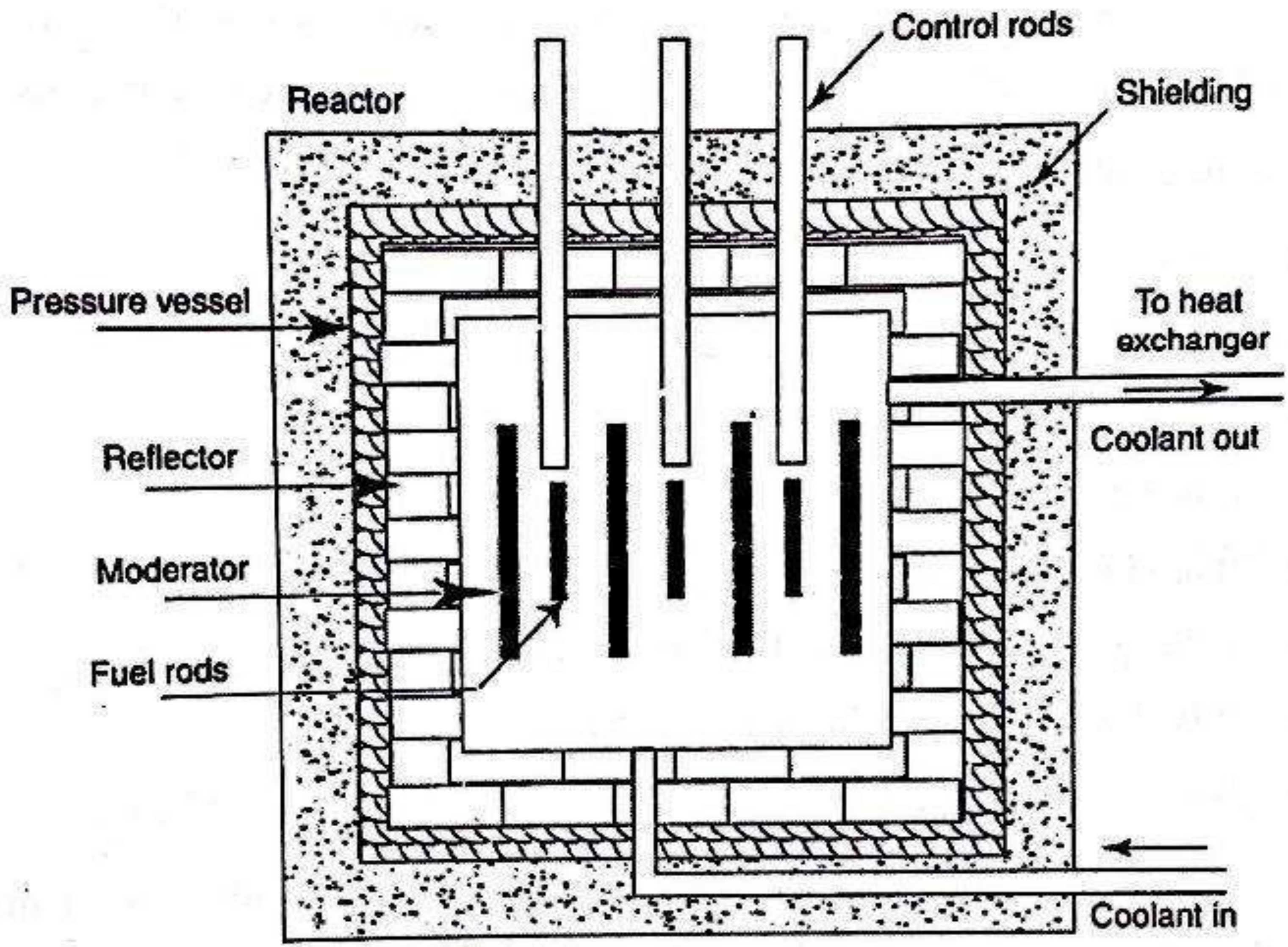
4) Reflector

5) Cooling System

6) Reactor Vessel

7) Biological Shielding

Components Of Nuclear Reactor



Reactor Core

- **Nuclear fission takes place in the reactor only.**
- **Nuclear fission produces large quantity of heat.**
- **The shape approximately a circular cylinder(0.5m – 15m)**

Control Rods:

- **They are used to control the chain reaction**
- **They are absorbers of neutrons.**
- **The commonly used control rods are made up of cadmium or boron.**

Moderator:

- **Moderators are used to slow down the fast neutrons.**
- **It reduces 2 MeV to an average velocity of 0.025 eV.**
- **H_2O (or) D_2O are used as moderators.**

Fuel Rods:

- **The fuel rods hold nuclear fuel in a nuclear power plant.**

Reflectors:

- **To prevent the leakage of neutrons to large extent.**
- **In Pressurised Heavy Water Reactor (PHWR), the moderator itself acts as reflectors.**
- **Graphite or beryllium**

Shielding:

- **To protect from harmful radiations the reactor is surrounded by a concrete wall of thickness about 2 to 2.5 m.**

Types of Reactor

1) Boiling Water Reactor(BWR)

2) Pressurised Water Reactor(PWR)

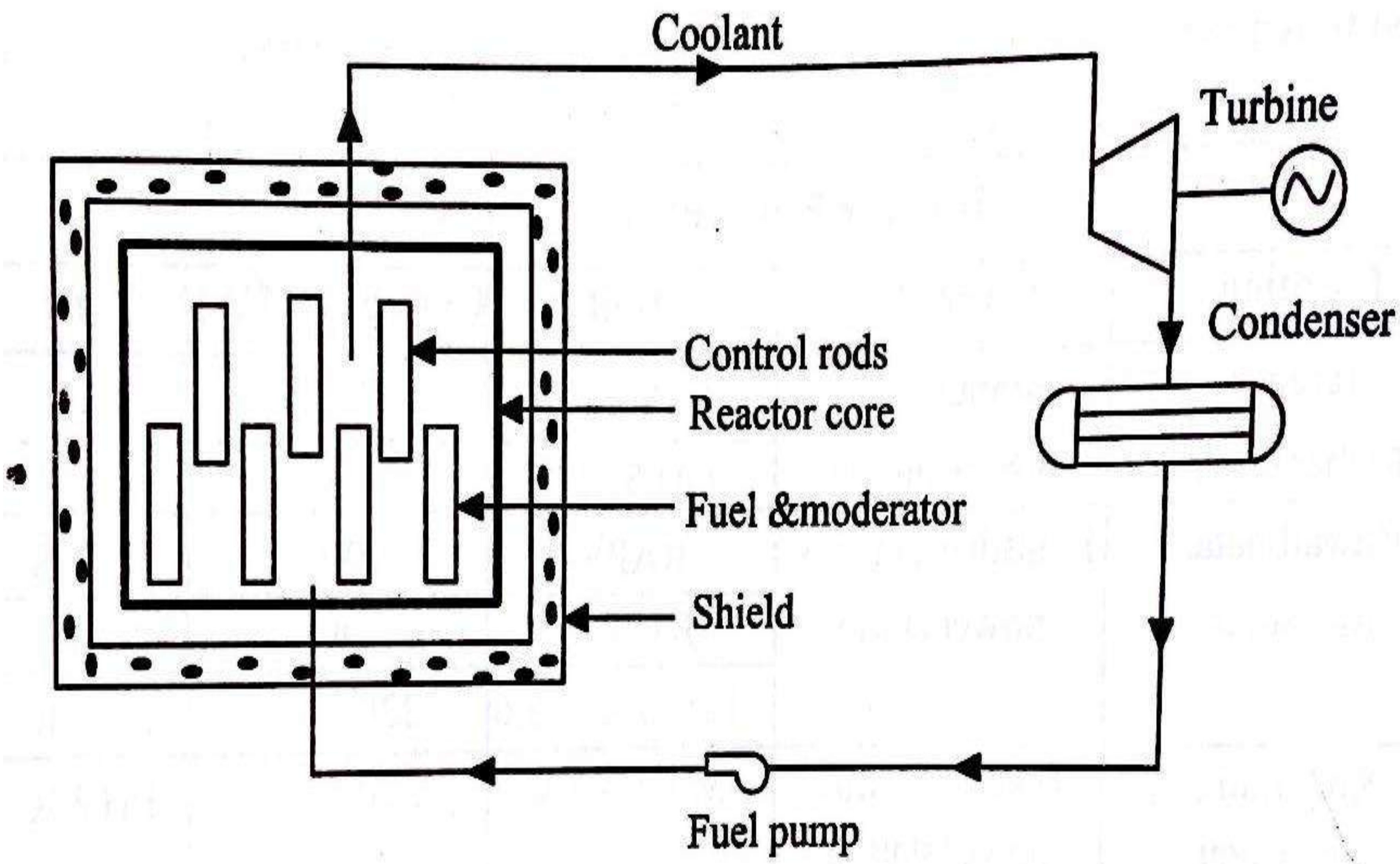
3) Fast Breeder Reactor(FBR)

4) Gas Cooled Reactor

5) Liquid Metal Cooled Reactor

6) CANDU Type Reactor

BOILING WATER REACTOR(BWR)



Fuel : Enriched Uranium

Moderator : Water

Coolant : Water

Advantages:

1)High exchanger circuit is eliminated
2)Higher thermal efficiency

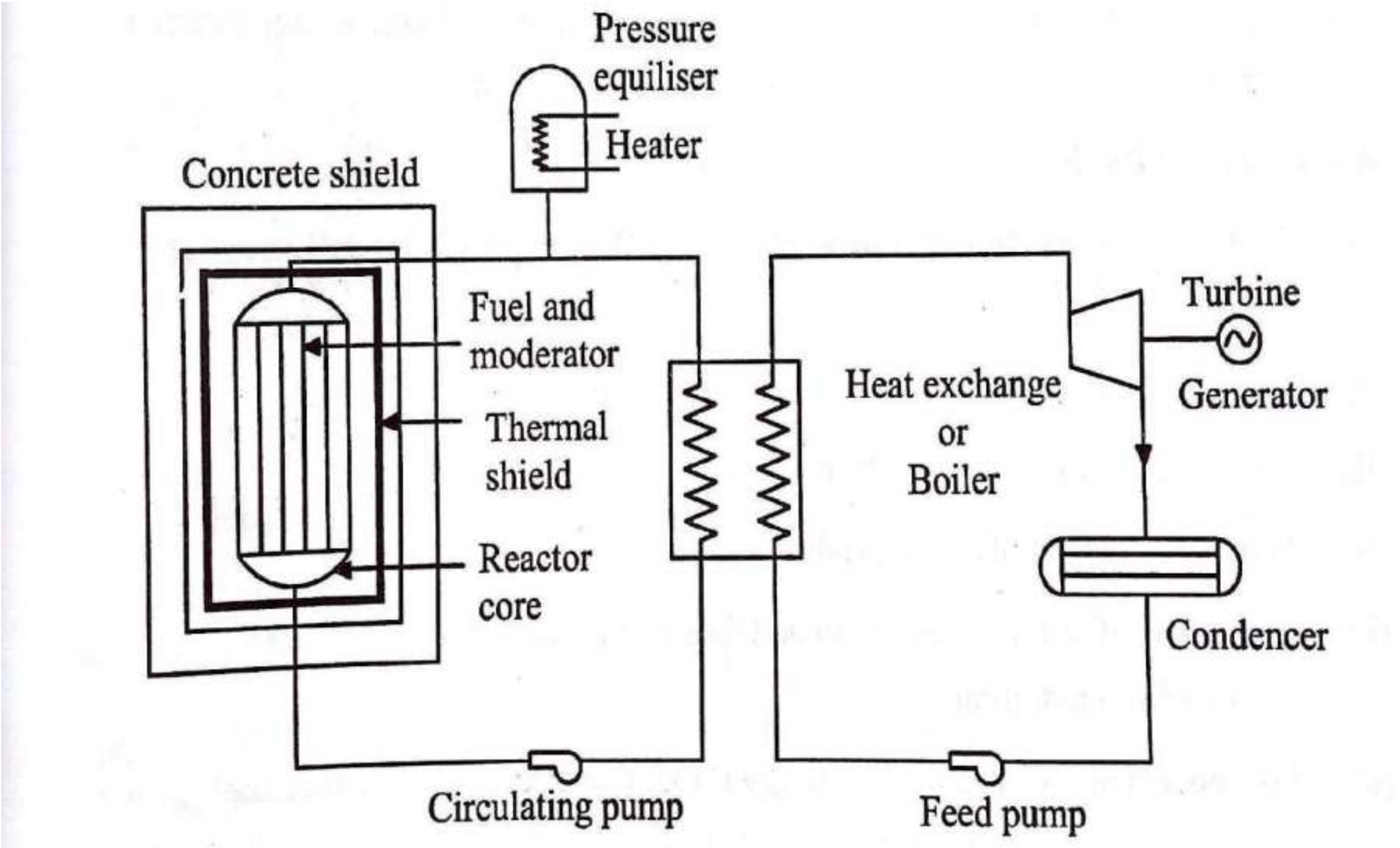
3)Pressure inside the vessel is considerably smaller than PWR.

4)The reactor is more stable than the PWR

Disadvantages:

- BWR cannot meet sudden increase in power demand
- Steam leaving the reactor is radioactive
- The power density of the reactor is low
- Size of the vessel is considerably large
- Possibility of radioactive contamination is present

PRESSURIZED WATER REACTOR(PWR)



Fuel	**: Both Natural &Enriched Uranium**
Moderator	**: Water**
Coolant	**: Water**

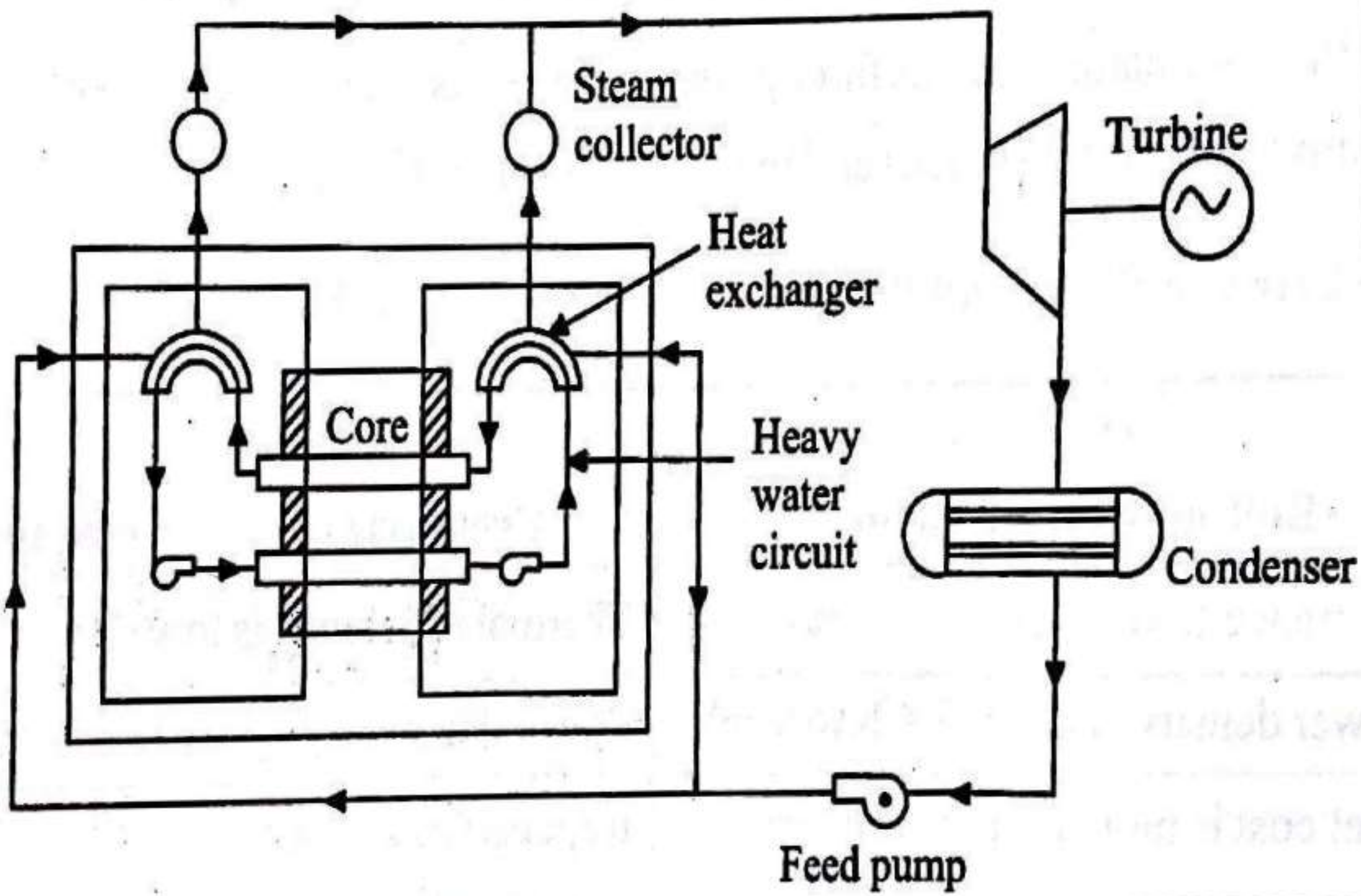
Advantages:

- Water is used as coolant, which is readily available with low cost
- The reactor is compact and high power density
- Only low number of control rods are required
- Inspection of turbine, condenser and feed pump is very easy as it is free from radiation
- Fuel cost is reduced as more energy is extracted per unit weight of fuel

Disadvantages:

- **High pressure in the primary circuit requires strong pressure vessel and so high capital cost.**
- **Due to low pressure in the secondary circuit, the thermodynamic efficiency is low (20%).**
- **Fuel suffers radiation damage and therefore reprocessing is difficult**
- **Fuel element fabrication is expensive**

CANDU REACTOR



Fuel	**: Natural Uranium**
Moderator	**: D_2O**
Coolant	**: D_2O**

Advantages

1) No control rods required
2) There is no need of enriched fuel
3) The cost of the reactor is less
4) Construction period of the plant is short

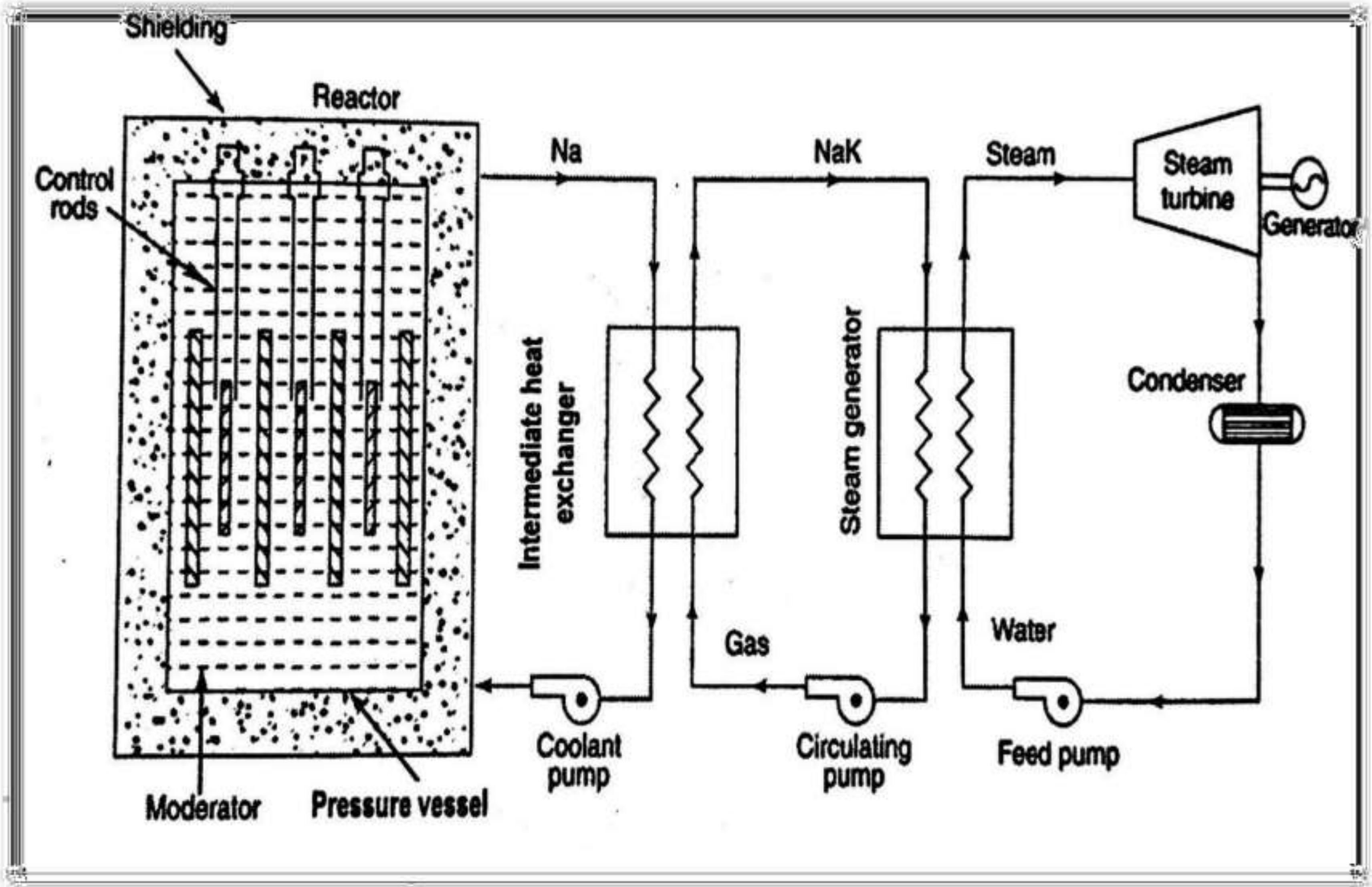
Disadvantages

1) Heavy water is costly
2) Leakage of water is a major problem
3) Power density is low

FAST BREDDING REACTORS

- **An enriched uranium (or) Plutonium(10%) is kept in the casing without moderator**
- **The casing is surrounded by blanket of depleted fertile uranium**
- **The thermal efficiency of the fast reactors is in the range of 40% - 45%**

SODIUM COOLED FAST BREEDER REACTOR (SFBR)



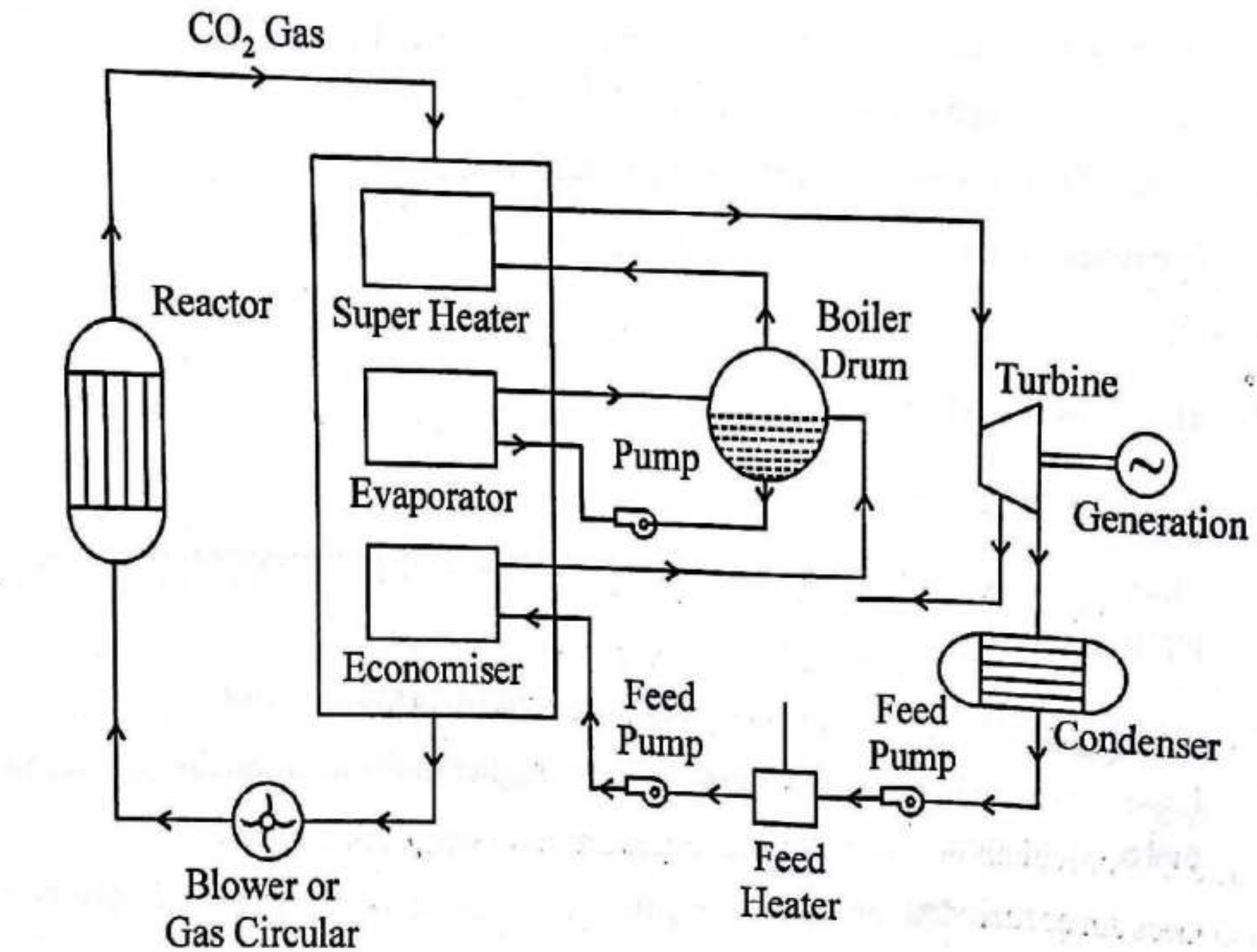
ADVATAGES OF SFBR

- **No moderator is required**
- **High breeding is possible**
- **It gives more power density**
- **High efficiency in the order of 40% can be obtained**
- **It ensures a better fuel utilization**

DISADVATAGES OF SFBR

- **It requires highly enriched fuel**
- **Handling of sodium is a major problem. Because it becomes hot and radioactive**
- **Special coolants are required**
- **Safety must be provided against melt-down**

GAS COOLED REACTORS



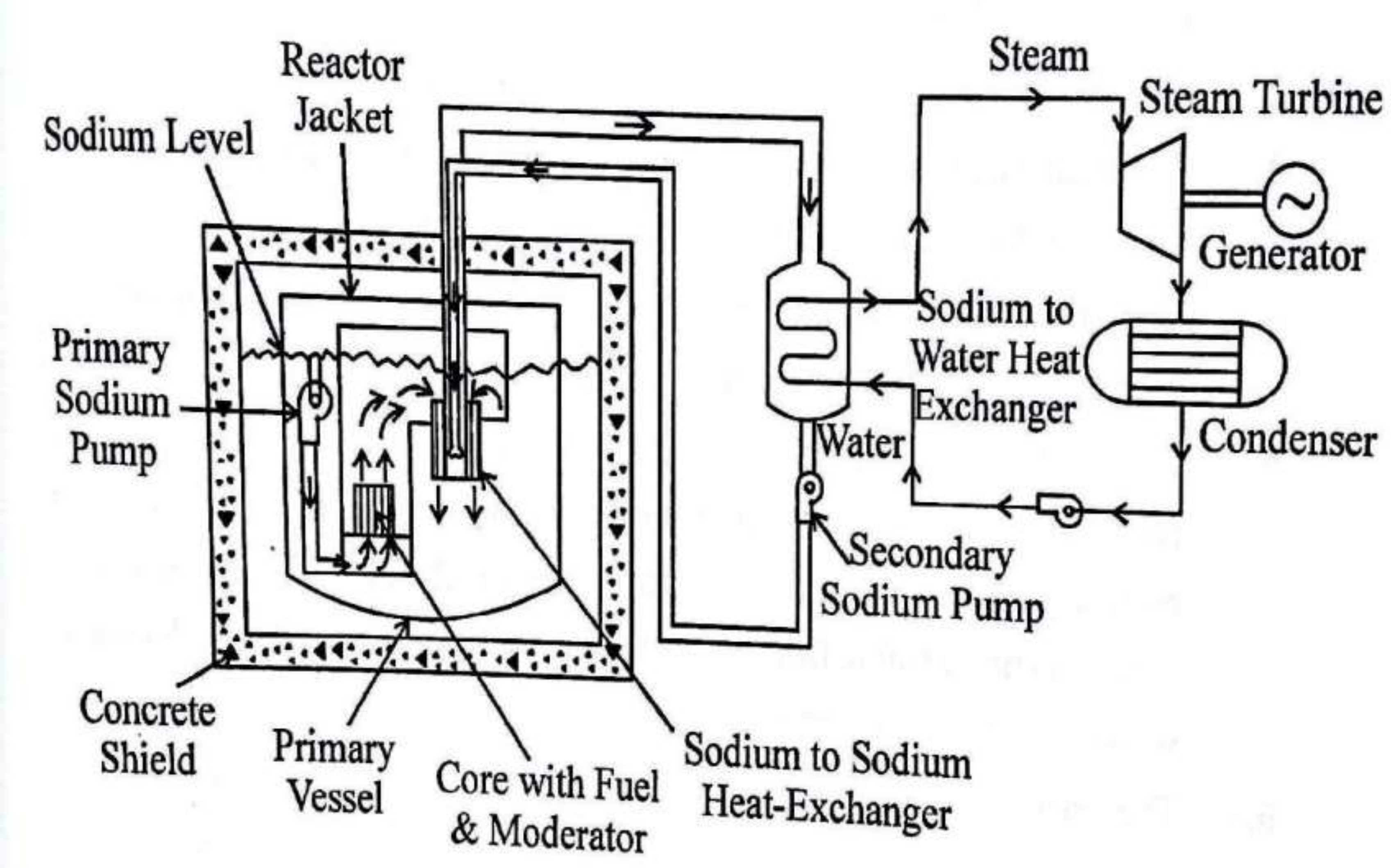
ADVANTAGES OF GAS COOLEDREACTOR

- **This is simpler fuel processing**
- **CO_2 as coolant completely eliminates the possibility of explosion in reactor**
- **There is no corrosion problem**

DISADVANTAGES OF GAS COOLED REACTOR

- **The loading of fuel is more elaborate and costly**
- **Power density is very low due to low heat transfer co-efficient**
- **The leakage of gas is a major problem if helium is used instead of CO2**

LIQUID METAL COOLED REACTOR



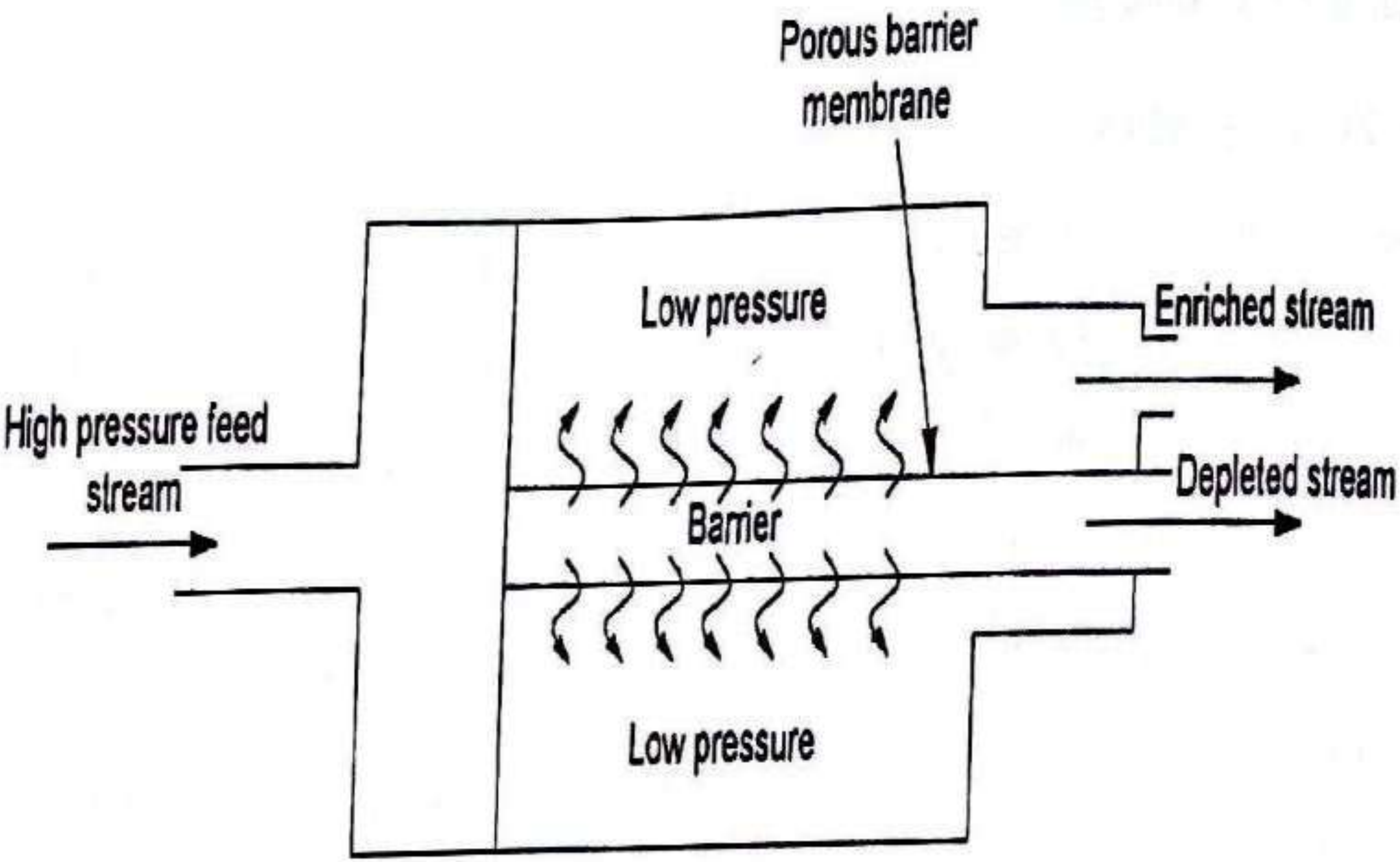
URANIUM ENRICHMENT

- **Enriched uranium is a type of uranium in which the percent composition of uranium-235 has been increased through the process of isotope separation.**
- **Natural uranium is 99.284% ^{238}U isotope, with ^{235}U only constituting about 0.711% of its mass. ^{235}U is the only nuclide existing in nature (in any appreciable amount) that is fissile with thermal neutrons.**

ENRICHMENT METHOD:

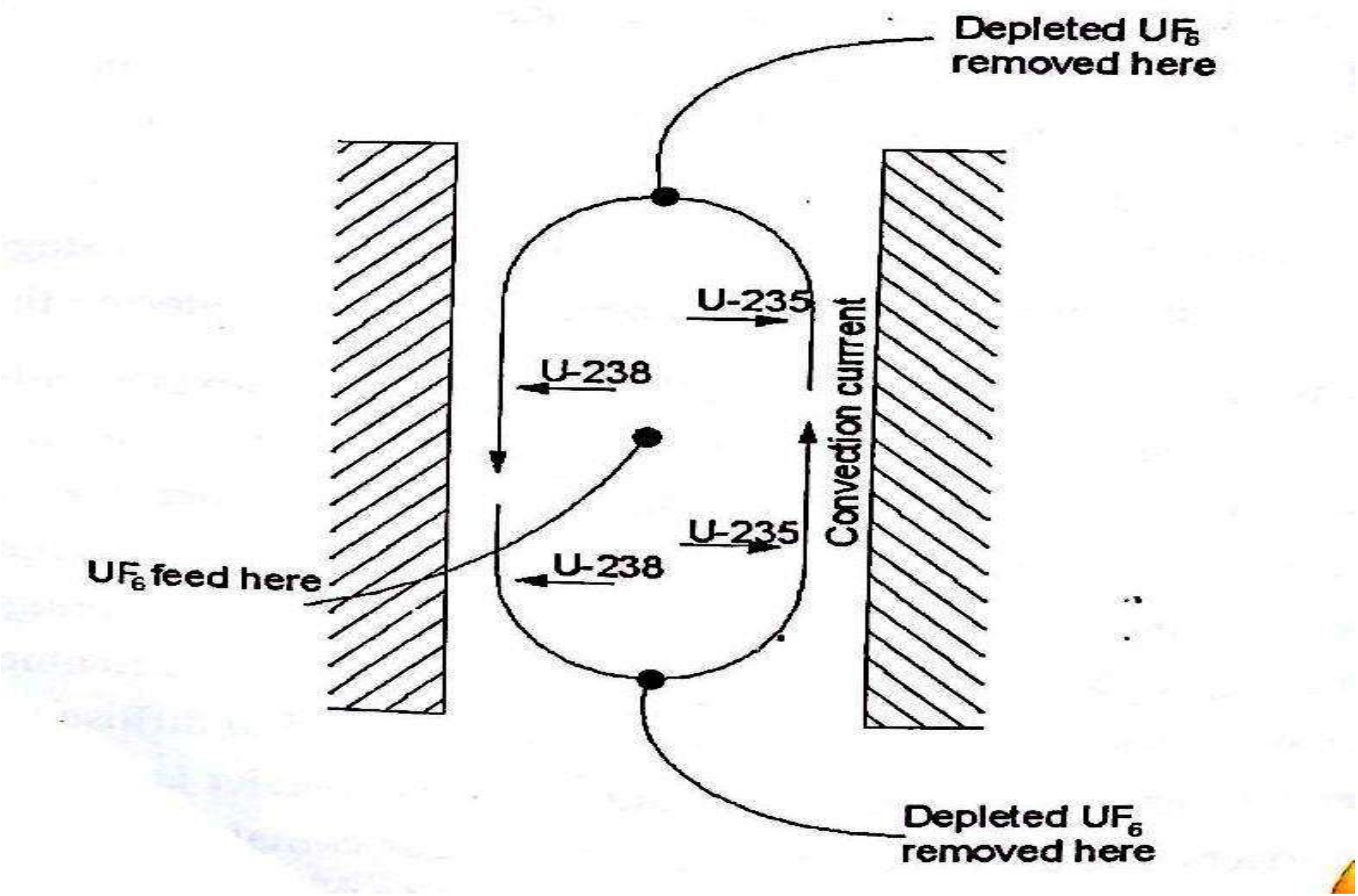
1)Gas centrifuge 2)Gaseous diffusion 3) Thermal diffusion

1) Gaseous diffusion



- **Gaseous diffusion is a technology used to produce enriched uranium by forcing gaseous uranium hexafluoride (hex) through semi-permeable membranes.**
- **This produces a slight separation between the molecules containing ^{235}U and ^{238}U.**

2. Thermal diffusion



- **Thermal diffusion utilizes the transfer of heat across a thin liquid or gas to accomplish isotope separation.**
- **The process exploits the fact that the lighter ^{235}U gas molecules will diffuse toward a hot surface, and the heavier ^{238}U gas molecules will diffuse toward a cold surface.**

Selection of Nuclear Power Plant

1. Proximity to load center
2. Population distribution
3. Land use
4. Meteorology
5. Geology
6. Hydrology
7. Seismology.

Safety Measures

- Proper design, plant layout and adequate shielding:
- Limits of air contamination levels in different zones of the plant:
- Source control by proper selection of materials/components:
- To shut down operating reactors
- To cool down reactors so as to remove heat from nuclear fuel
- To contain radioactive materials

Safety in Modern

Figure 3.21 shows the *defence-in-depth* strategy of design of modern nuclear power plants. Current plants may have some or all of these defences. The defences vary depending on the type of plant, nation constructing them, use (civilian, military, naval vessels) and age.

1. First layer of defence is the inert, ceramic quality of the uranium oxide itself.
2. Second layer is the air tight zirconium alloy of the fuel rod.
3. Third layer is the reactor pressure vessel made of steel more than a dozen centimeters thick.
4. Fourth layer is the pressure resistant and air tight containment building.
5. Fifth layer is the reactor building or newer power plants in a second outer containment building.

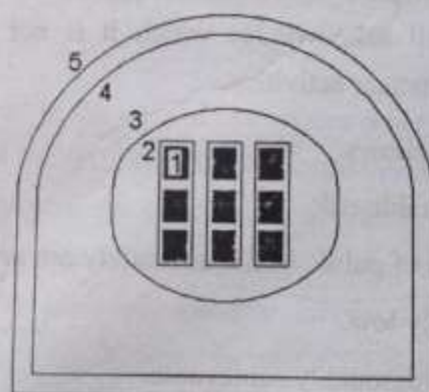


Figure 3.21 Defence-in-depth safety system in modern nuclear plant

UNIT - IV

POWER FROM RENEWABLE ENERGY

About Renewable Energy,

- Hydro Power Energy
- Wind Energy
- Tidal Energy
- Geo Thermal Energy
- Bio-gas Energy
- Solar Energy

Hydro Power Energy

Hydropower is a commercial source of energy which supplies 30% of the total electricity of the world.

Potential Energy → **Kinetic Energy**

↓

Mechanical Energy

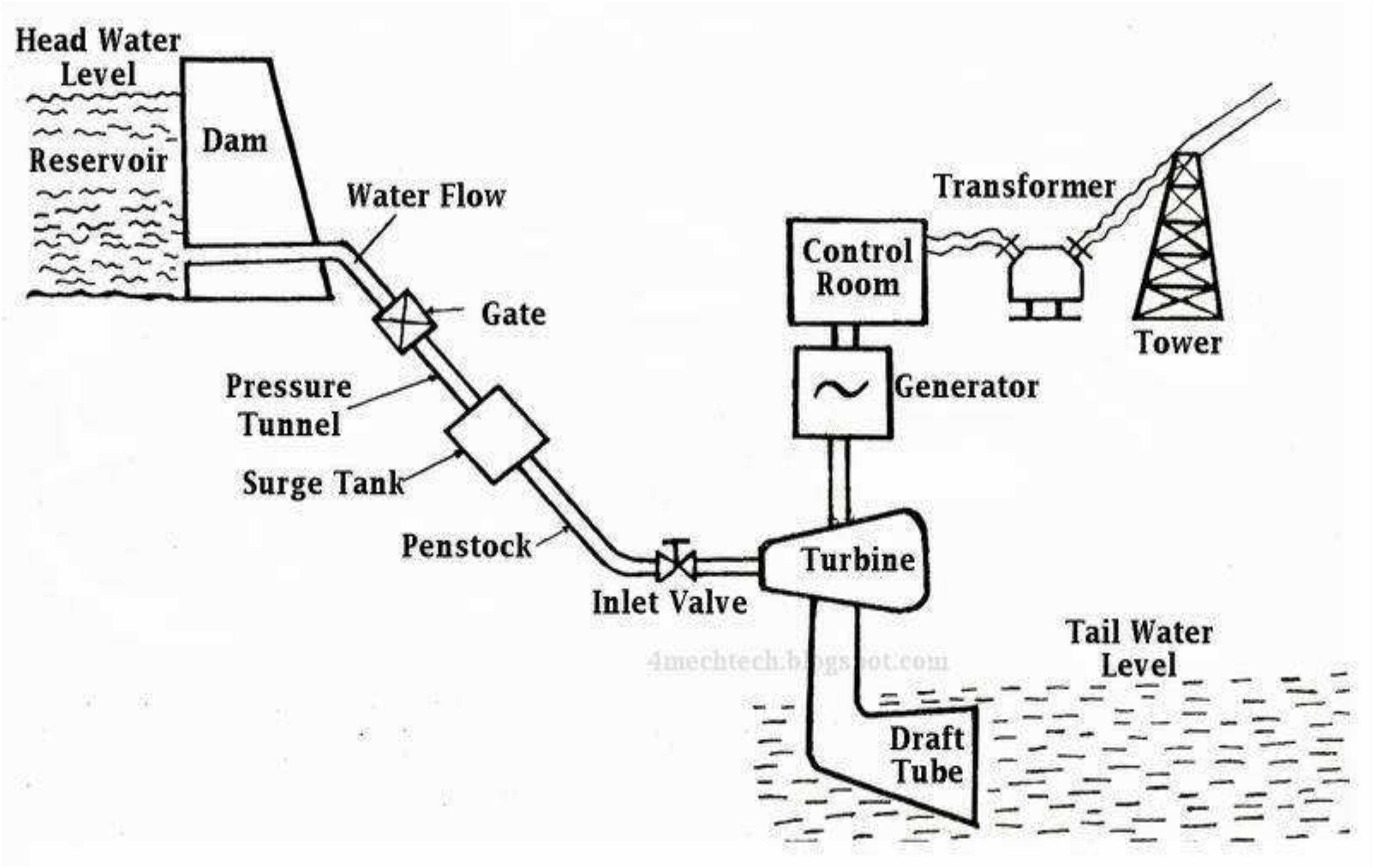
↓

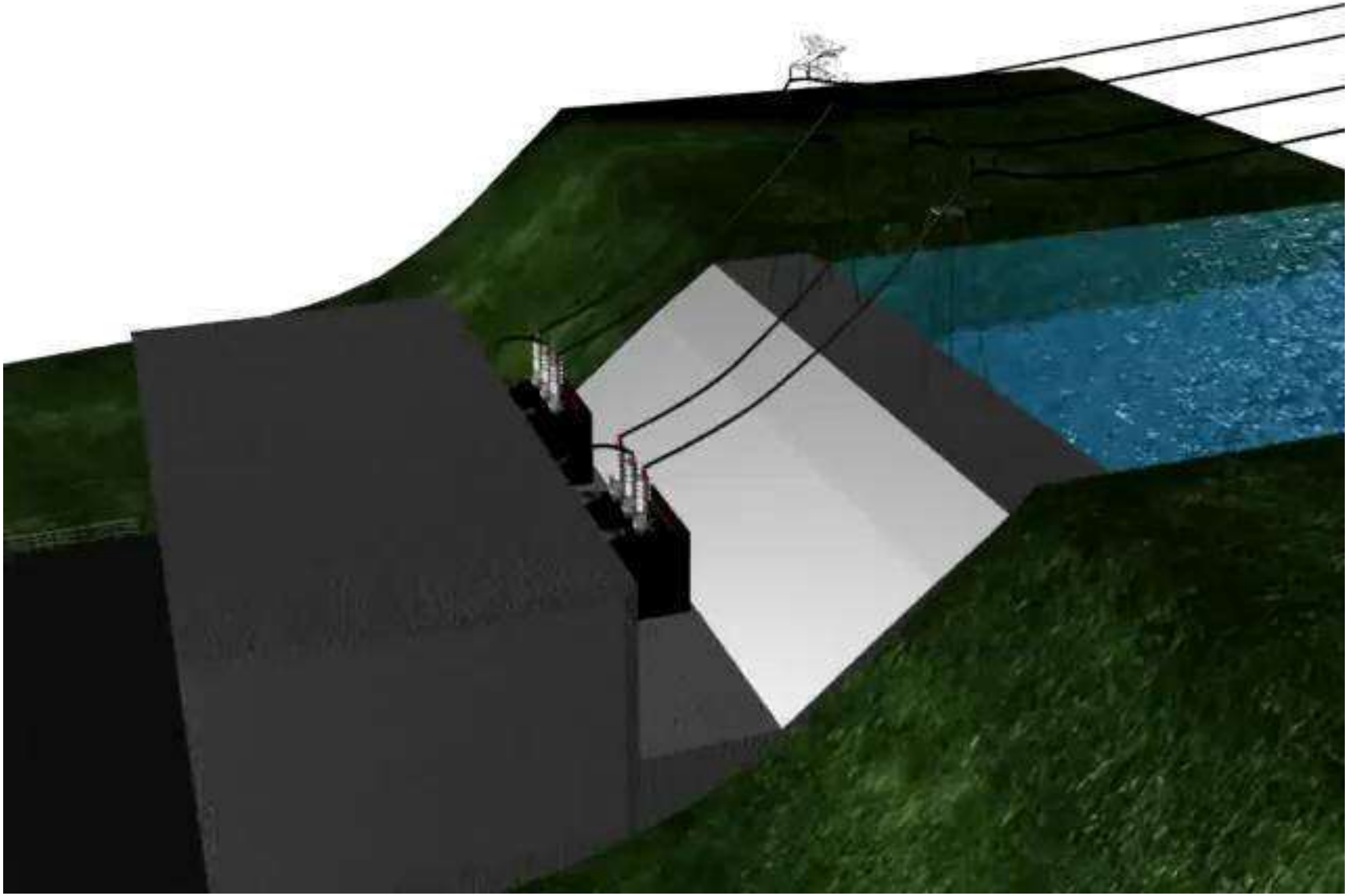
Electrical Energy

Components of Hydro Power Plant

- Reservoir
- Dam
- Spillways
- Trash Rack
- Fore bay
- Water Tunnel
- Penstock
- Surge tanks
- Water turbine
- Draft tubes
- Tailrace
- Power house and equipment

Layout Of Hydro Power Plant





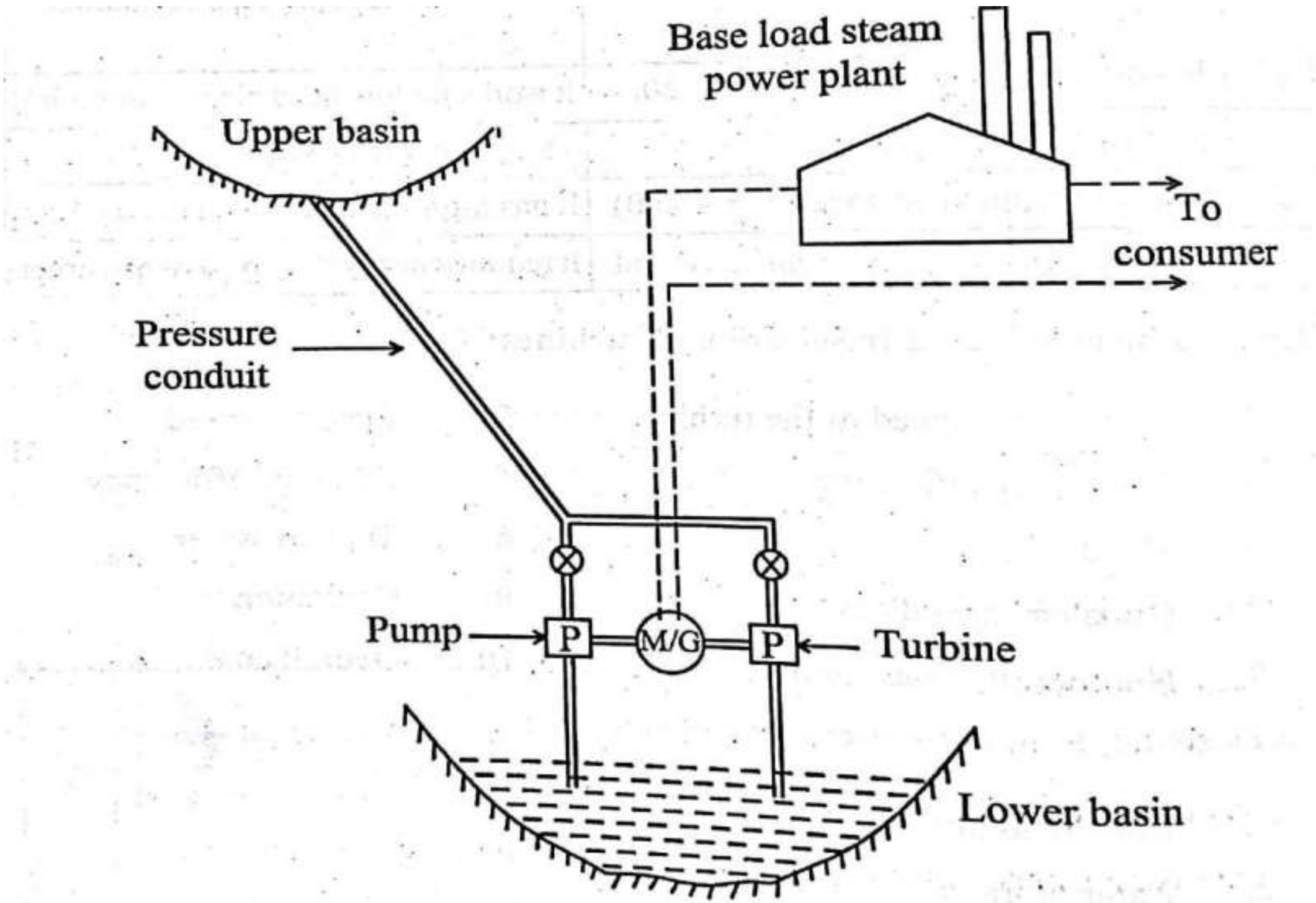
Advantages

- **They are highly reliable**
- **Maintenance and operation & Running cost are very low**
- **No fuel charges & No stand by losses & No ash handling problem**
- **Number of operation required is small**
- **Along with power generation, these plants are also used for flood control and irrigation**

Disadvantages

- The initial cost of the plant is very high
- The time taken far erection of such plants is considerably longer
- It is purely dependent on rainfall. If the rainfall is not adequate in a year, then this plant cannot be utilized

Pumped Storage Power plant



Site Selection For Hydro Power Plant

- **Water availability**
- **Water storage**
- **Water head**
- **Various Geological investigations**
- **Environmental aspects**
- **Consideration of water pollution effects**

Water Turbines

Kinetic Energy → Mechanical Energy

Classification:

1. The action of water flowing

a) Impulse turbine

→ **Pelton Wheel**

b) Reaction turbine

→ **Francis & Kaplan turbine**

2. The direction of flow water:

a) Tangential flow

b) Radial flow

c) Axial flow

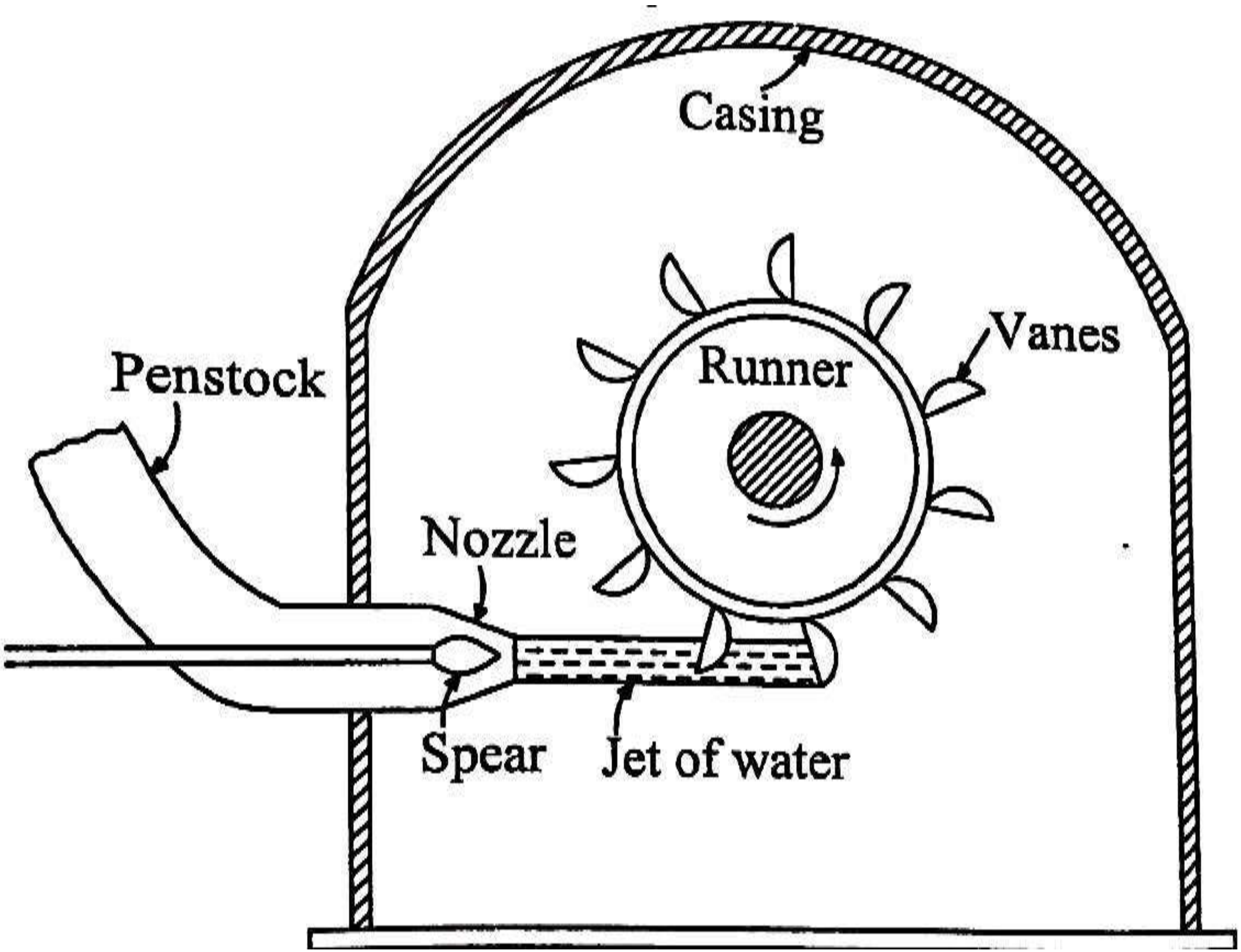
3. The head and quantity of water:

a) High head (above 250m)

b) Medium head (60m – 250m)

c) Low head (less than 60m)

Pelton Wheel Turbine



Components

- **Runner**
- **Nozzle**
- **Spear**
- **Brake jet**
- **Bucket**
- **Casing**
- **Penstock**

Advantages

- **It is a tangential flow impulse turbine**
- **High head turbine (more then250m).**
- **It's have more hydraulic efficiency.**
- **It's involves less maintenance work**

Disadvantages

- **Low specific speed**
- **Water is admitted only in the form of jet**
- **The runner consists of a circular disc with a number of buckets evenly spaced around its periphery**

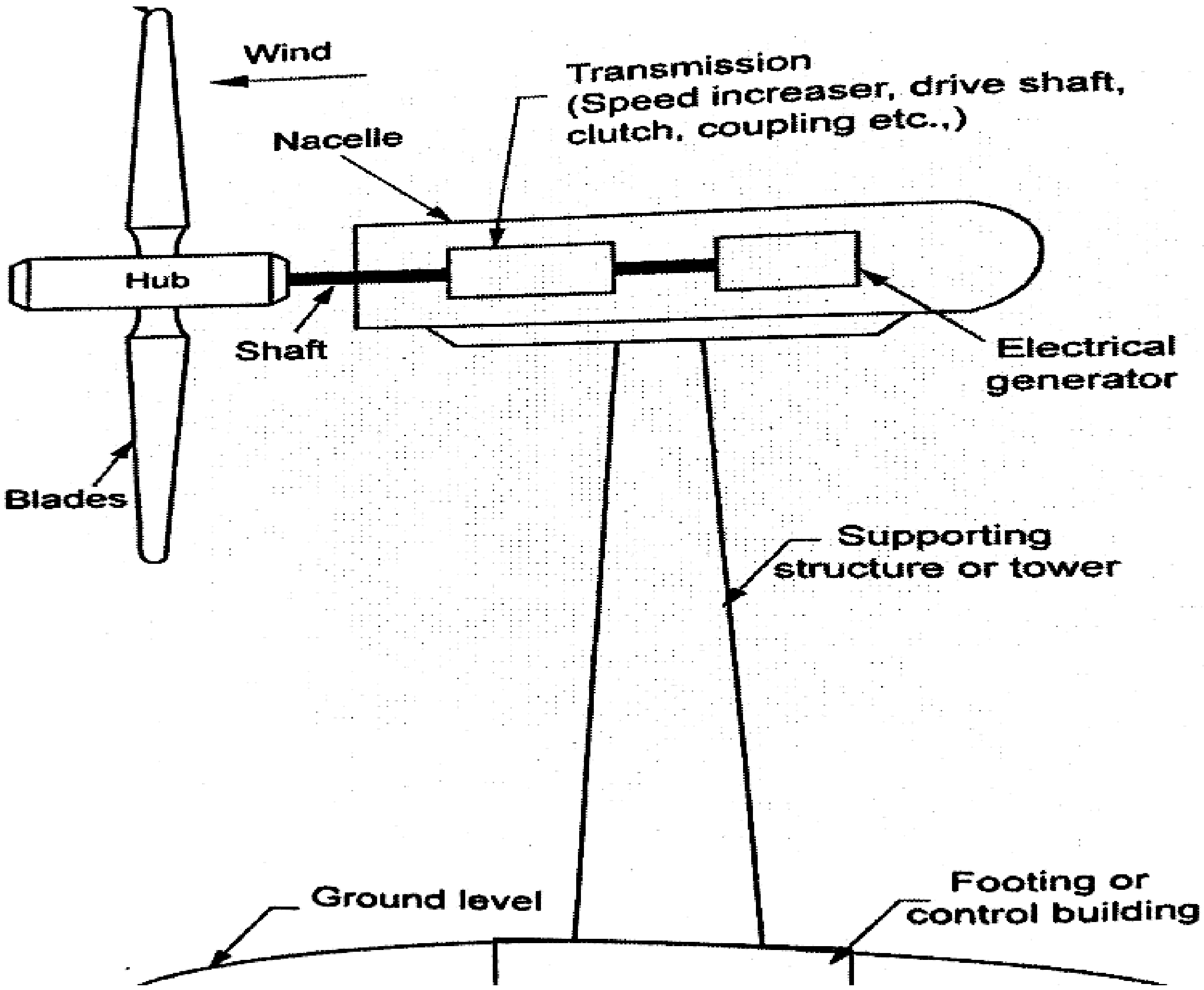
WIND ENERGY

WIND ENERGY → **MECHANICAL ENERGY** → **ELECTRICAL ENERGY**

Basic features:

1. **Drag is in the direction of airflow**
2. **Lift in perpendicular to the direction of airflow**

Construction Of Wind Mill (or) Turbine



Components

1. Wind Turbine
    a) Nacelle
    b) Rotor
    c) Hub and Shaft
    d) Anemometer
2. Transmission system
3. Electric generator
4. Yaw control system
5. Storage
6. Energy converter
7. Towers

Advantages

1. Clean Energy
2. Free from pollution
3. Place ability
4. Decentralised
5. Domestic
6. Remote area supply

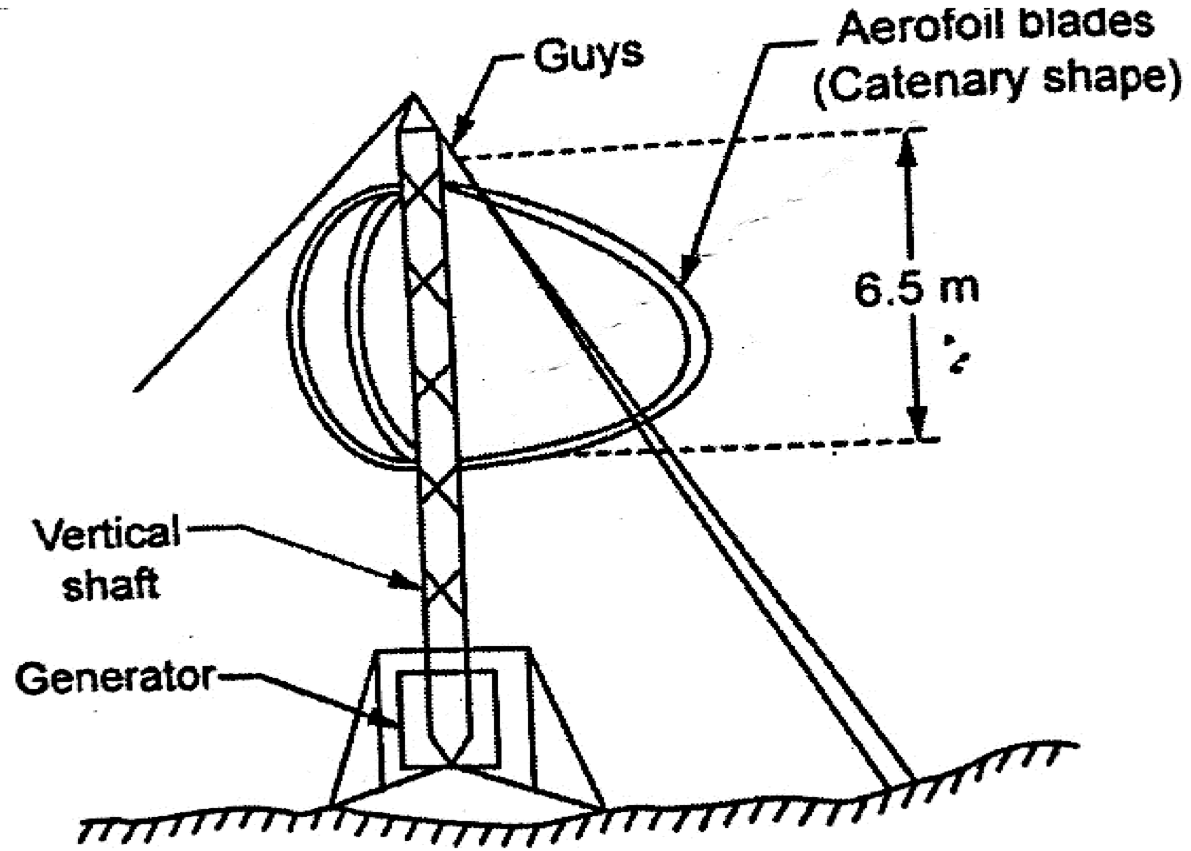
Disadvantages

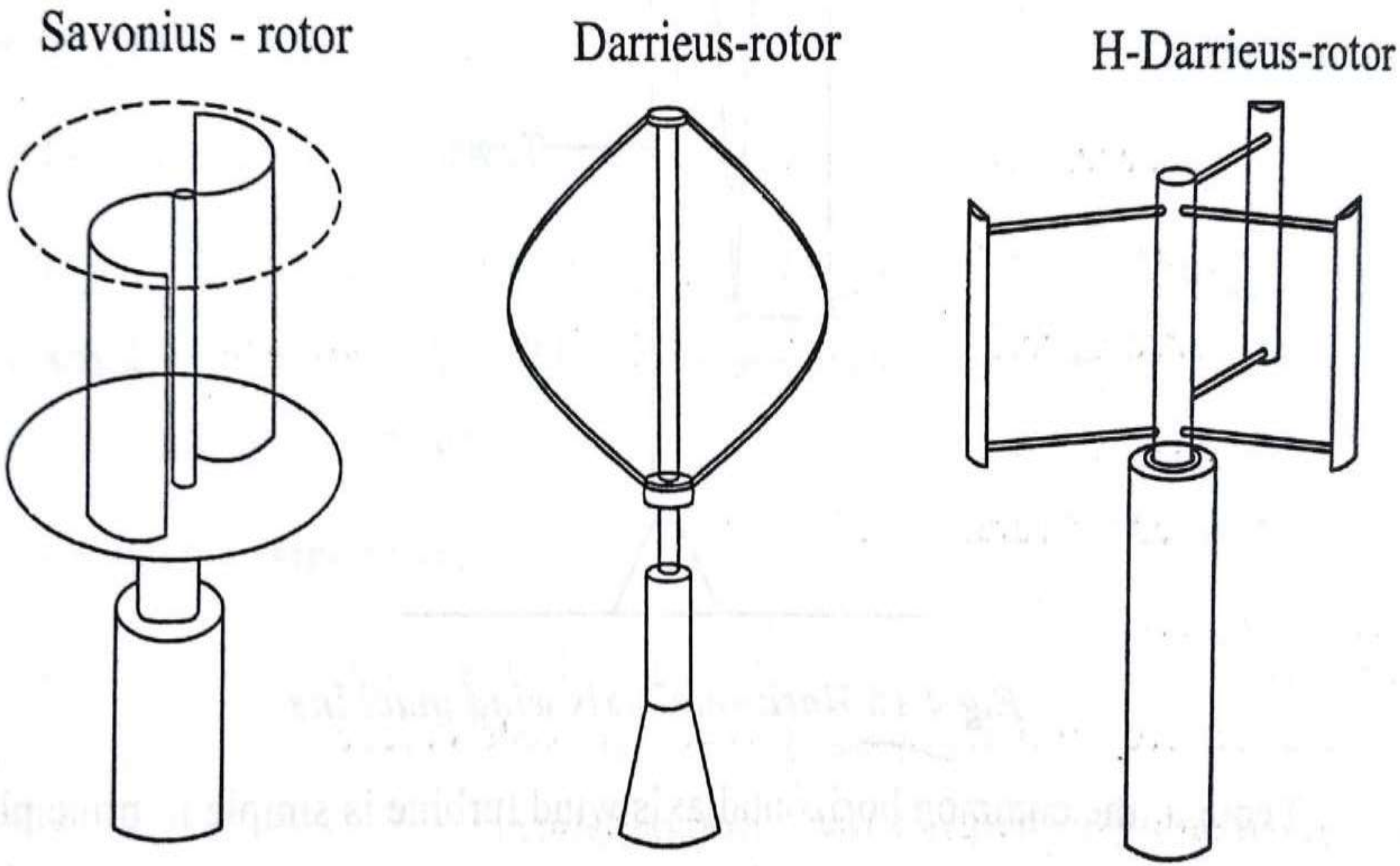
1. Reliability
2. Expense
3. National security
4. Noise
5. Wild life

Types Of Wind Turbine

1. Horizontal axis wind turbine

2. Vertical axis wind turbine




Savonius - rotor
Darrieus-rotor
H-Darrieus-rotor

TIDAL ENERGY

- **The periodic rise and fall of sea water level which are carried by the action of sun and moon on water of the earth is called "Tide"**
- **Nearly 70 % of the tide produces force due to moon and remaining 30% by the sun**

Modes Of Generation Of Tidal

1. Single basin arrangement

One way systems

Two way systems

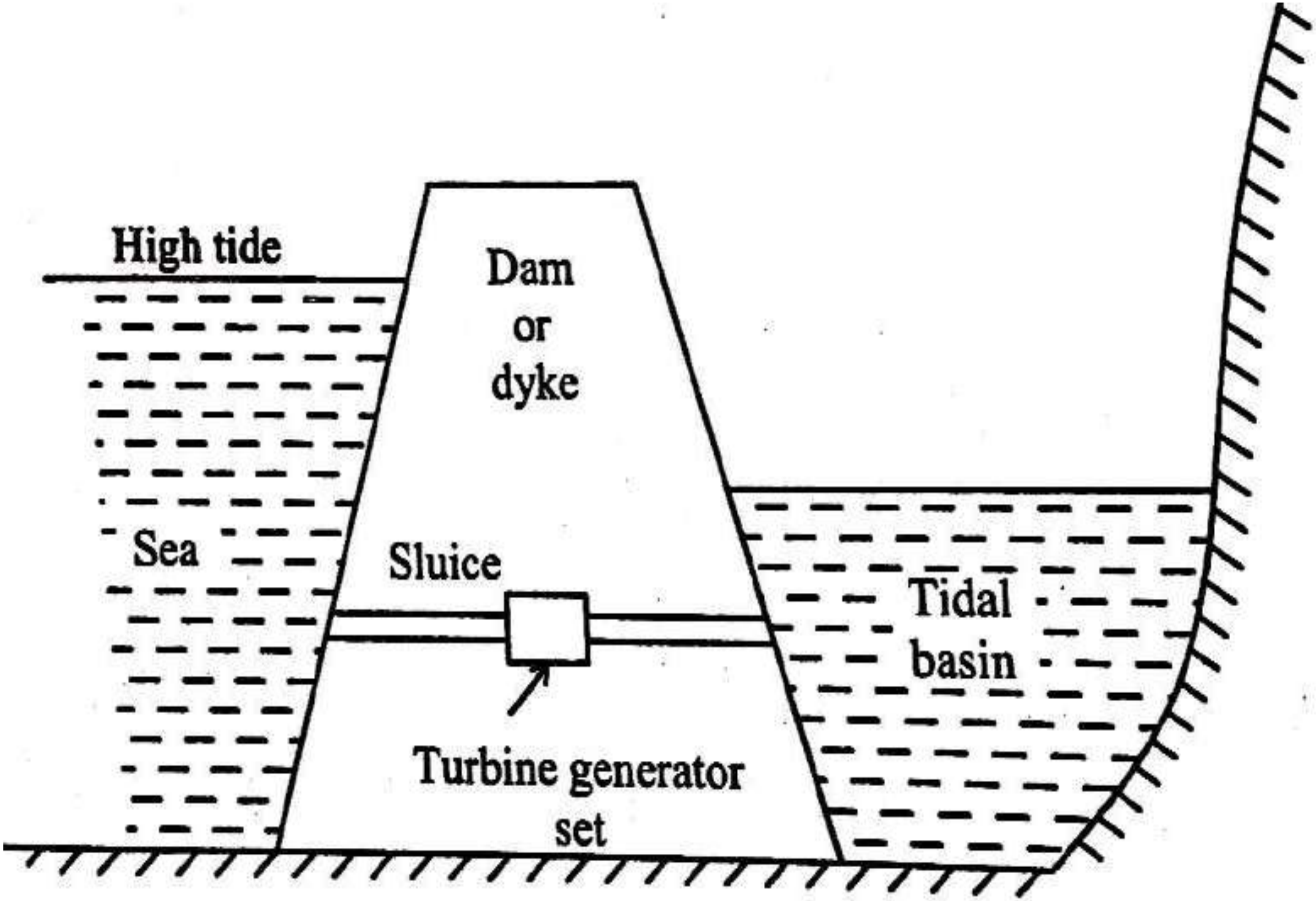
Two way with pump storage

2. Double basin arrangement

Simple double basin

Double basin with pump

Single Basin Arrangement



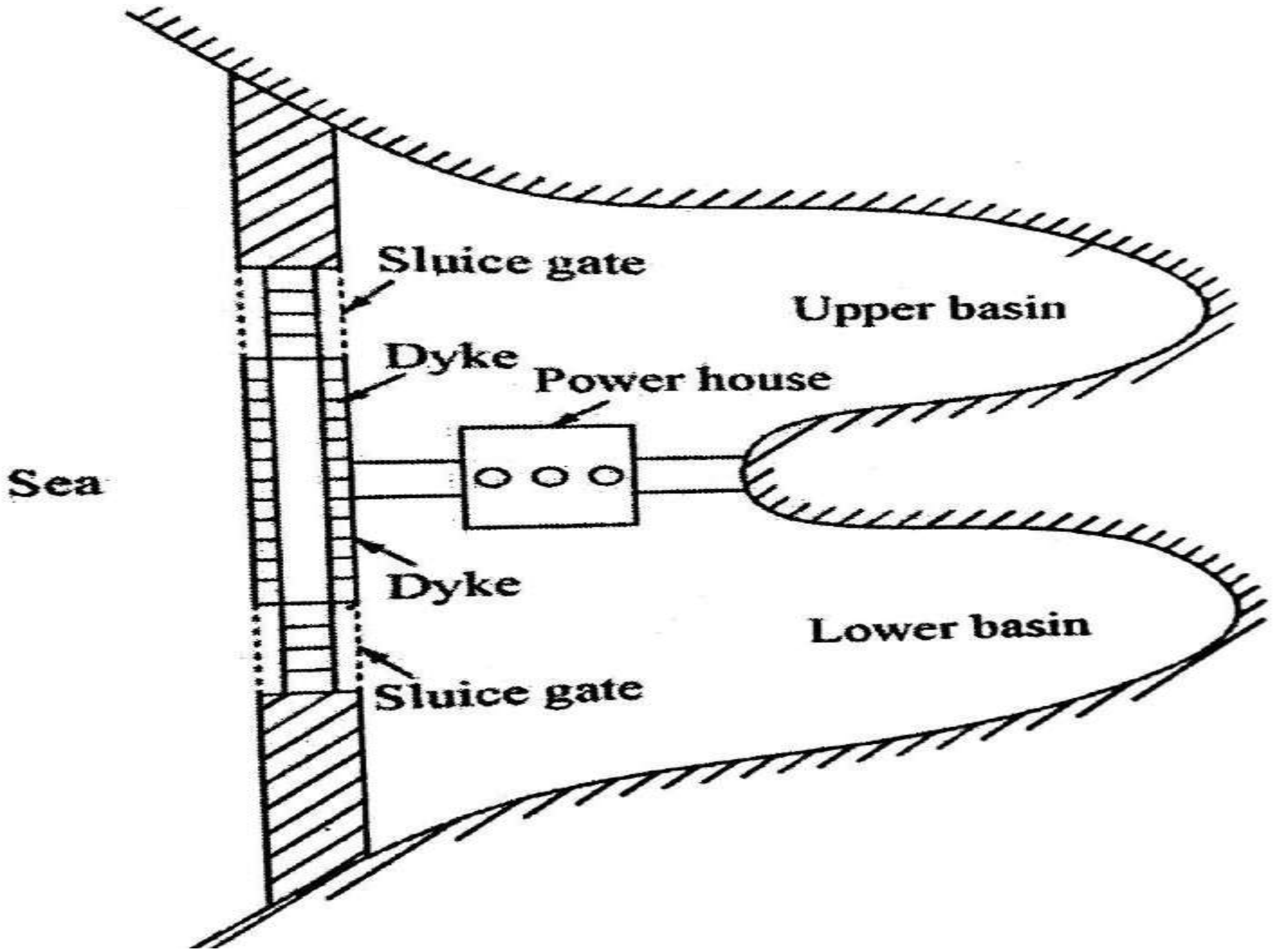
Advantages:

- A single basin cannot generate power continuously, through pumped storage may be used still fluctuations occurs continuously

Disadvantages:

- Its construction of the civil work becomes more extensive

Double Basin Arrangement



Advantages:

- **A double basin scheme can provide power continuously or on demand**

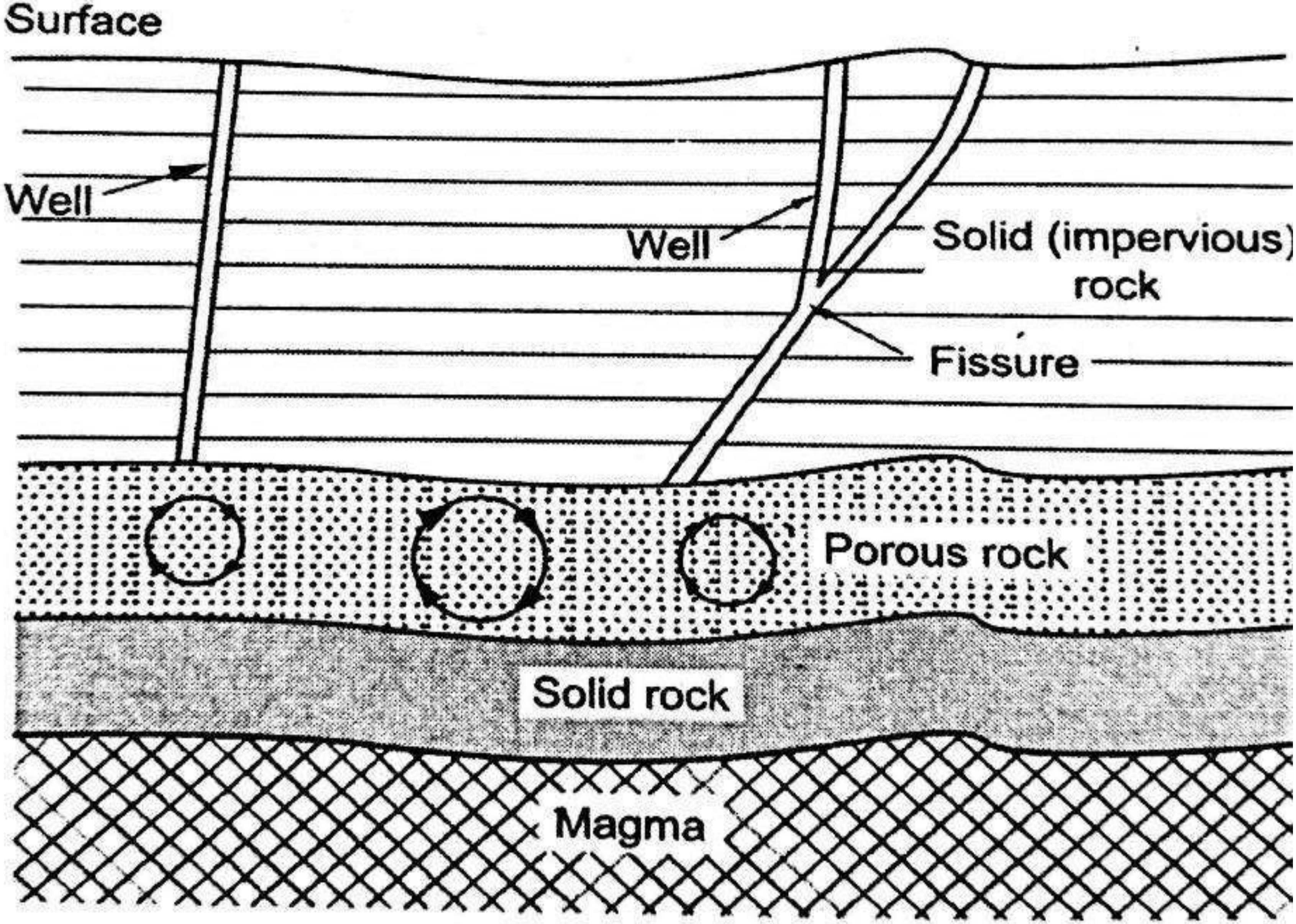
Disadvantages:

- **Its construction of the civil work becomes more extensive**

GEO THERMAL ENERGY

THERMAL ENERGY → MECHANICAL ENERGY → ELECTRICAL ENERGY

- **Thermal(heat) energy in the earth crust**
- **The more readily heat is in the upper crust(10Km) constitutes a potentially useful and inexhaustible source of energy**
- **The average temperature at a depth of 10 Km is 200^{0}C**
- **The average temperature at a depth of 32 Km is 3000^{0}C**



Surface
Well
Well
Solid (impervious)
rock
Fissure
Porous rock
Solid rock
Magma

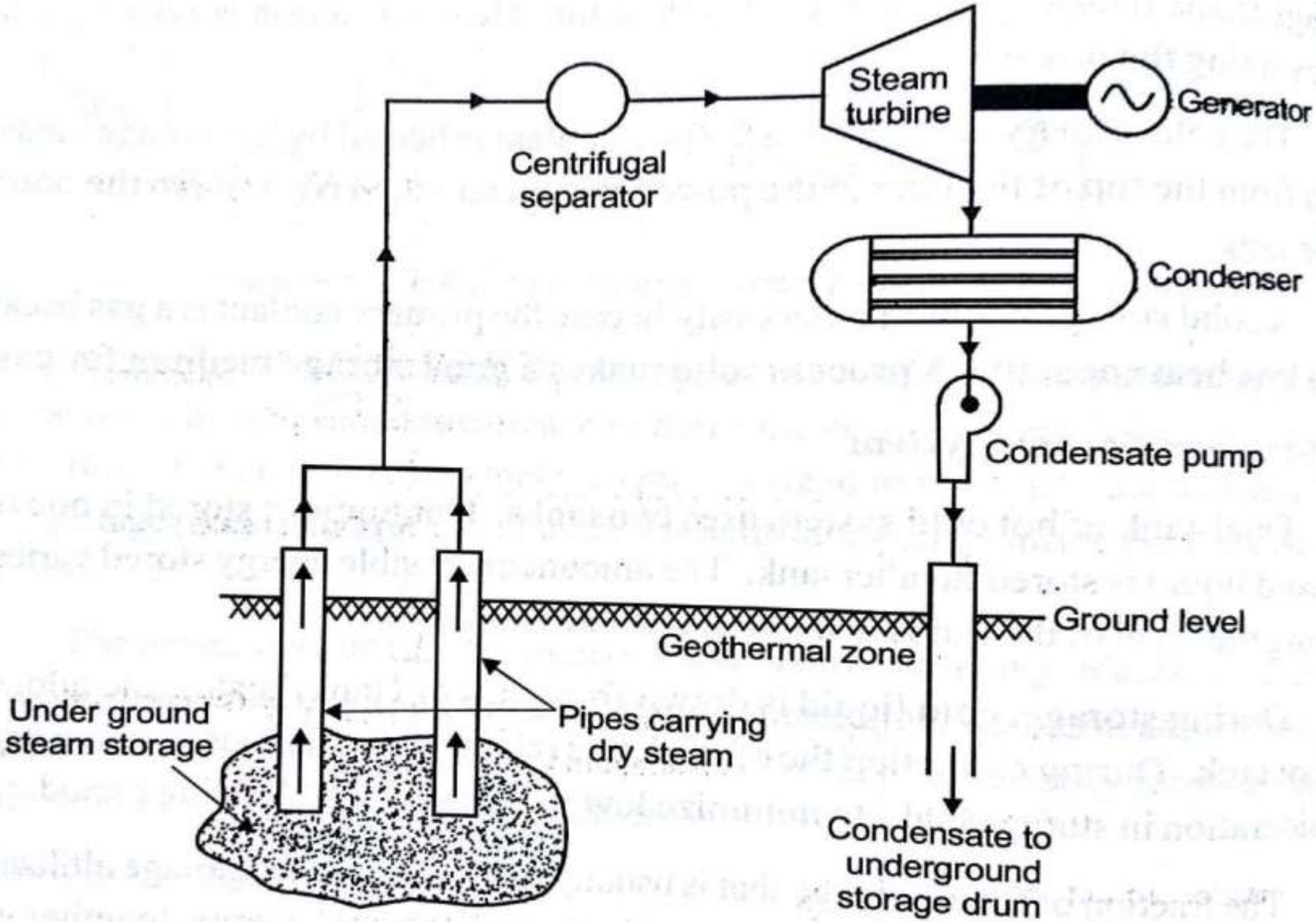
Uses Of Geothermal Energy

1. Space heating
2. Industrial processes
3. Drying
4. Green house
5. Aquaculture
6. Hot water
7. Melting snow

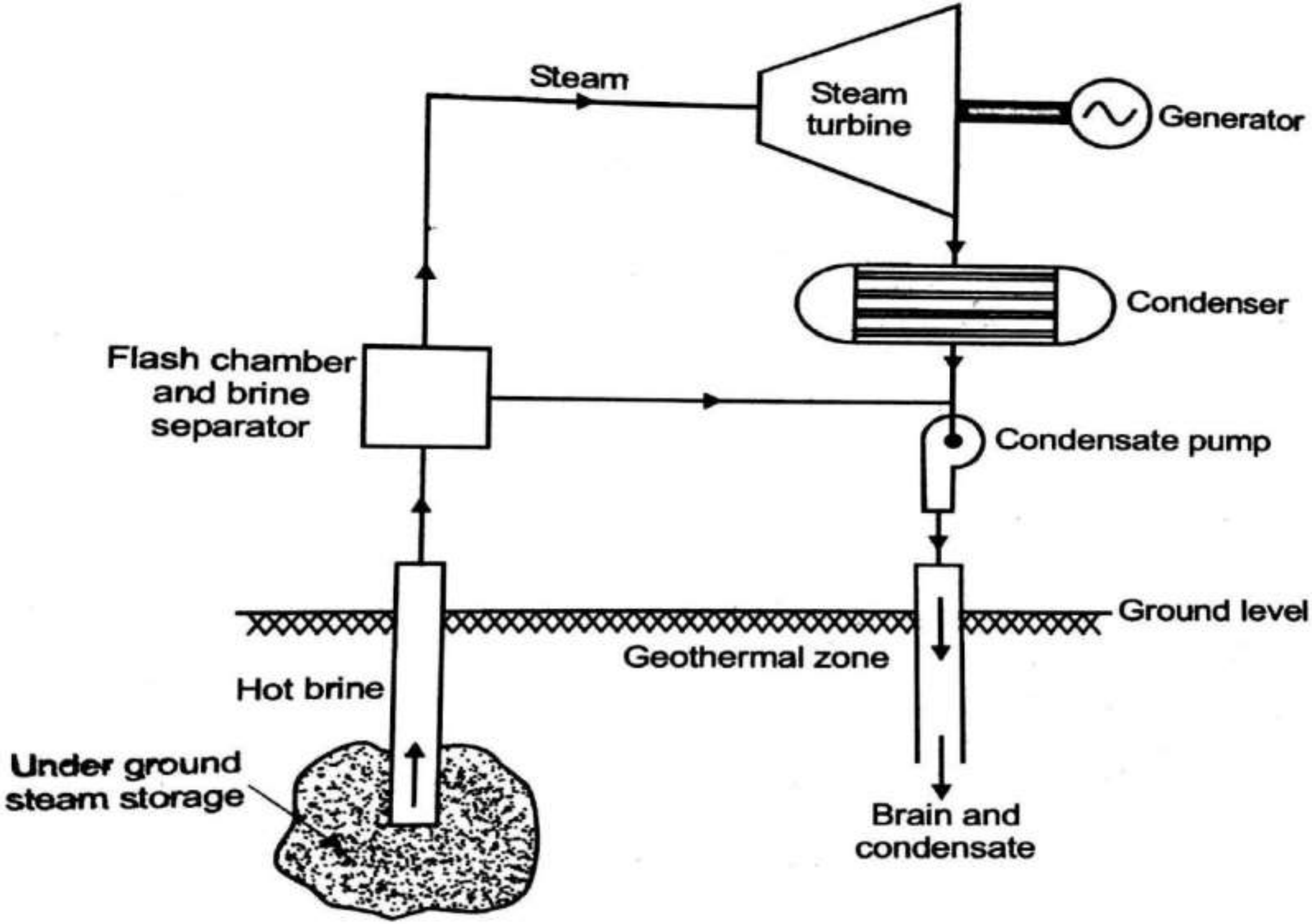
Types Of Geothermal Energy

1. Dry type (or)Vapour- Dominated
2. Wet type (or) Liquid-Dominated

Dry (Or)vapour-dominated



Wet Type (or)liquid-dominated



Advantages:

1. **Geothermal energy is cheaper**
2. **It is versatile in its use**
3. **It delivers greater amount of net energy**

Disadvantages:

1. **Drilling operation is noisy**
2. **Large areas are needed for exploitation of geothermal energy**
3. **Low overall efficiency**

BIO-GAS POWER PLANT

- **The bio-gas plant is used to generate low calorific value biogas ($CH_4 + CO_2$) fuel.**
- **Biogas plant converts wet biomass into biogas by the process of anaerobic fermentation**
- **Biogas plants are very popular in India especially in rural areas**

COMPOSITION OF BIOGAS

Methane (CH_4) = 55 to 60%

Carbon dioxide (CO_2) = 35 to 40%

Hydrogen (H2) = 5%

H_2S and O_2 = Traces

Raw Materials For Biogas

1. **Animal wastes**

   Cow ,cattle and elephant dung,

   Fish waste, Leather waste

2. **Agriculture wastes**

   Crop residue, Sugarcane trash, cotton and textile wastes

3. **Industrial wastes**

   Sugar, paper and tannery etc..

4. **Human waste**

Biofuels

- **Fuel wood**
- **Charcoal**
- **Bio-ethanol**
- **Bio-gas**
- **Producer gas**
- **Vegetable oils**

Important Parts Of A Biogas Plant

- **Digester tank where biomass undergoes decomposition**
- **Inlet tank where biomass is mixed with water**
- **Outlet tank where slurry of the biomass is collected**

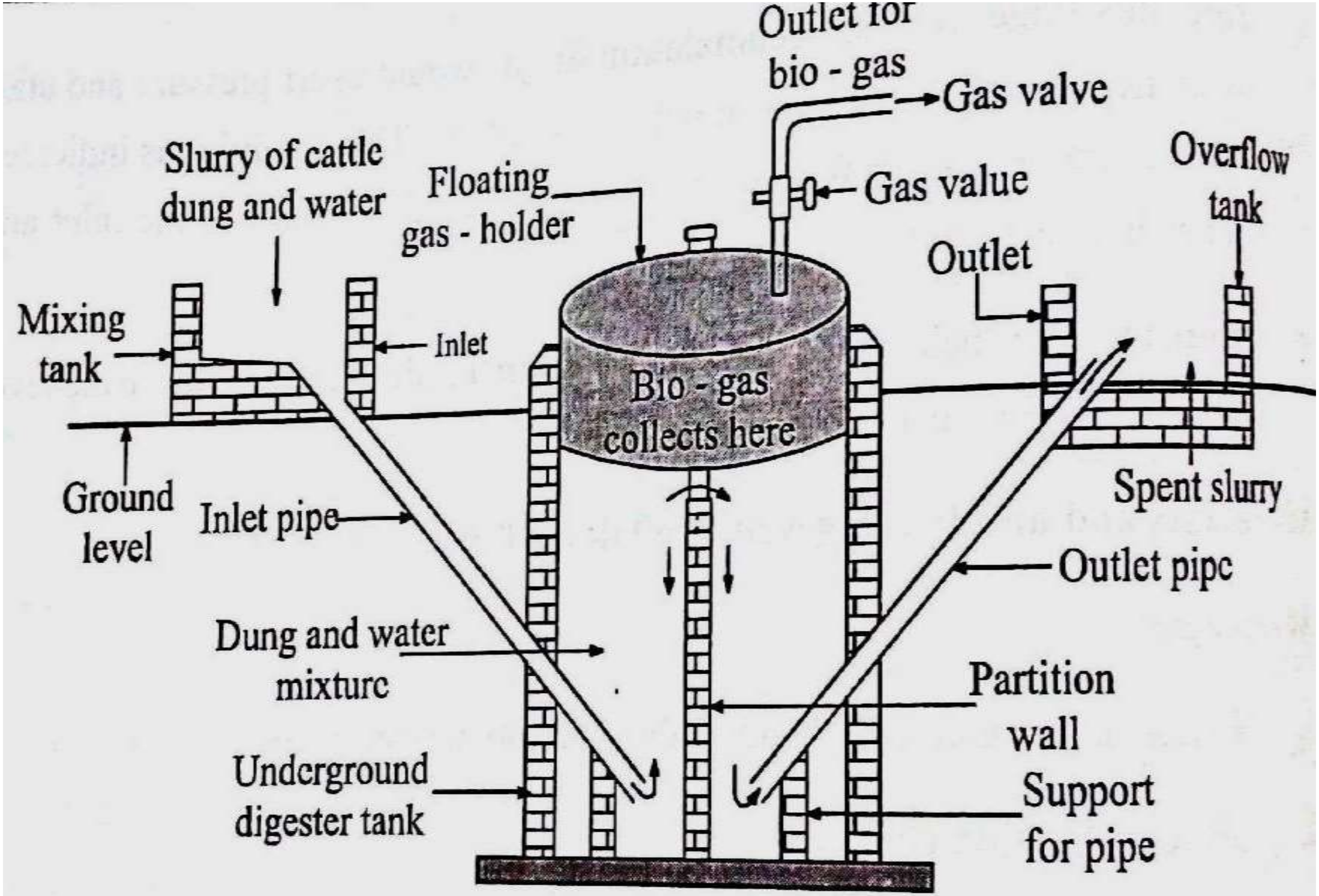
Classification Of Bio Gas Plants

Continuous type bio gas plant

- Single stage continuous type
- Two stage continuous type

Batch type bio gas plant

- Fixed dome type
- Floating dome type



Floating gas - holder type bio-gas plant

Advantages:

- **Gas pressure is constant**
- **Scum formation is very less**
- **The danger of explosion is completely eliminated as there is no possibility of mixing of biogas and external air**
- **No gas leakage problem**
- **Volume of gas stored is visible directly**

Disadvantages

- **Construction cost is high**
- **Steel parts are liable to corrosion**
- **Short life & Maintenance cost is high**

FUEL CELL

- **A fuel cell is a device which use hydrogen and oxygen to create an electric current**

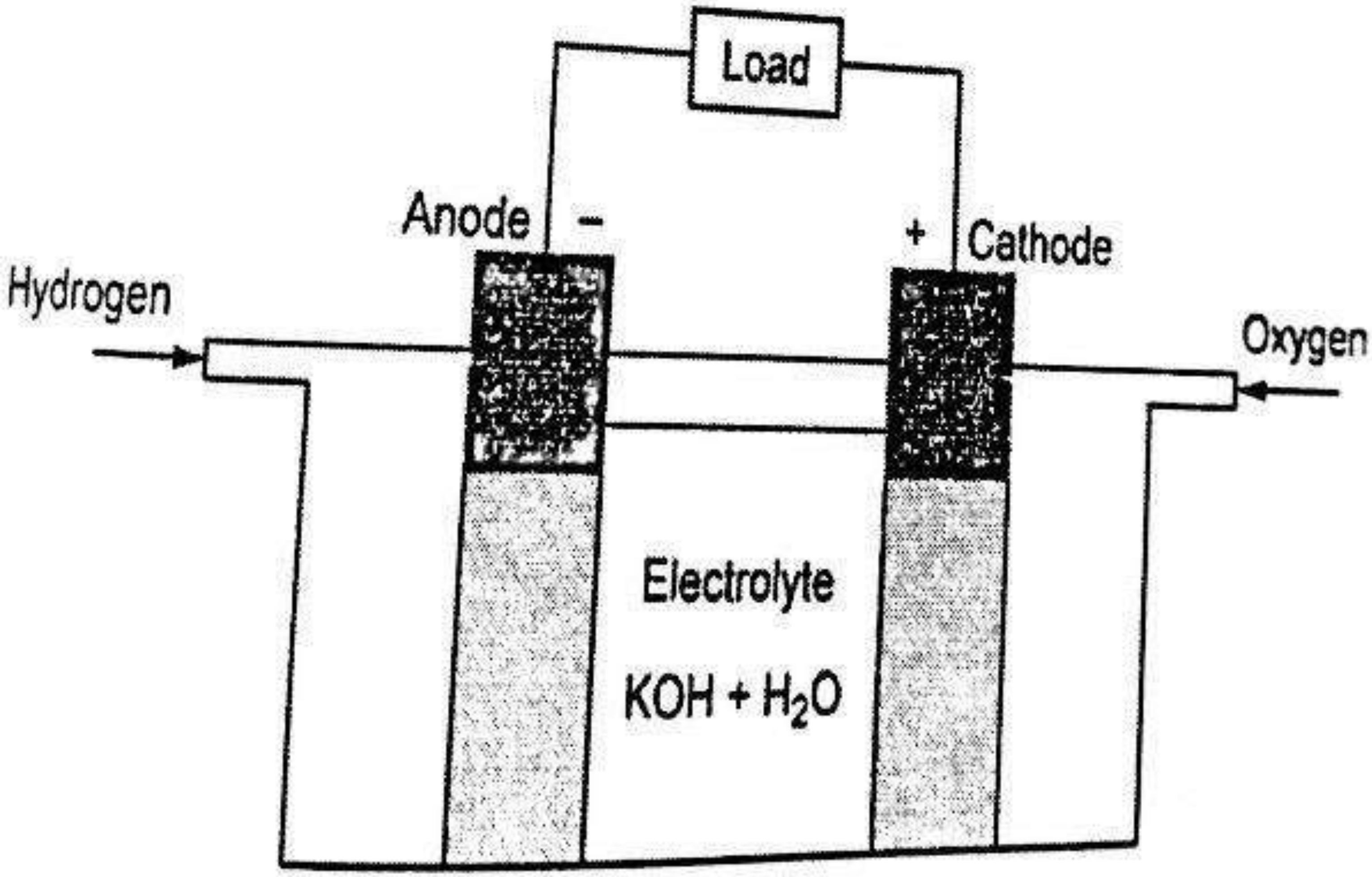
Types of fuel cell:

- **Polymer electrolyte membrane fuel cell**
- **Direct methanol fuel cell**
- **Alkaline fuel cell**
- **Phosphoric acid fuel cell**
- **Molten carbonate fuel cell**
- **Solid oxide fuel cell**
- **Reversible fuel cell**

Components Of A Fuel Cell

- **Membrane electrode assembly**
  - **a) Anode**
  - **b) Cathode**
- **Catalyst**
- **Chemistry of fuel cell**

Hydrogen – Oxygen Fuel Cell



Two types of hydrogen fuel cell,

1. **Low temperature cell**

   Temperature = 90^0C Pressure

   = 4 atmospheric

2. **High Pressure cell**

   Temperature = 300^0C

   Pressure = 45 atmospheric

Advantages

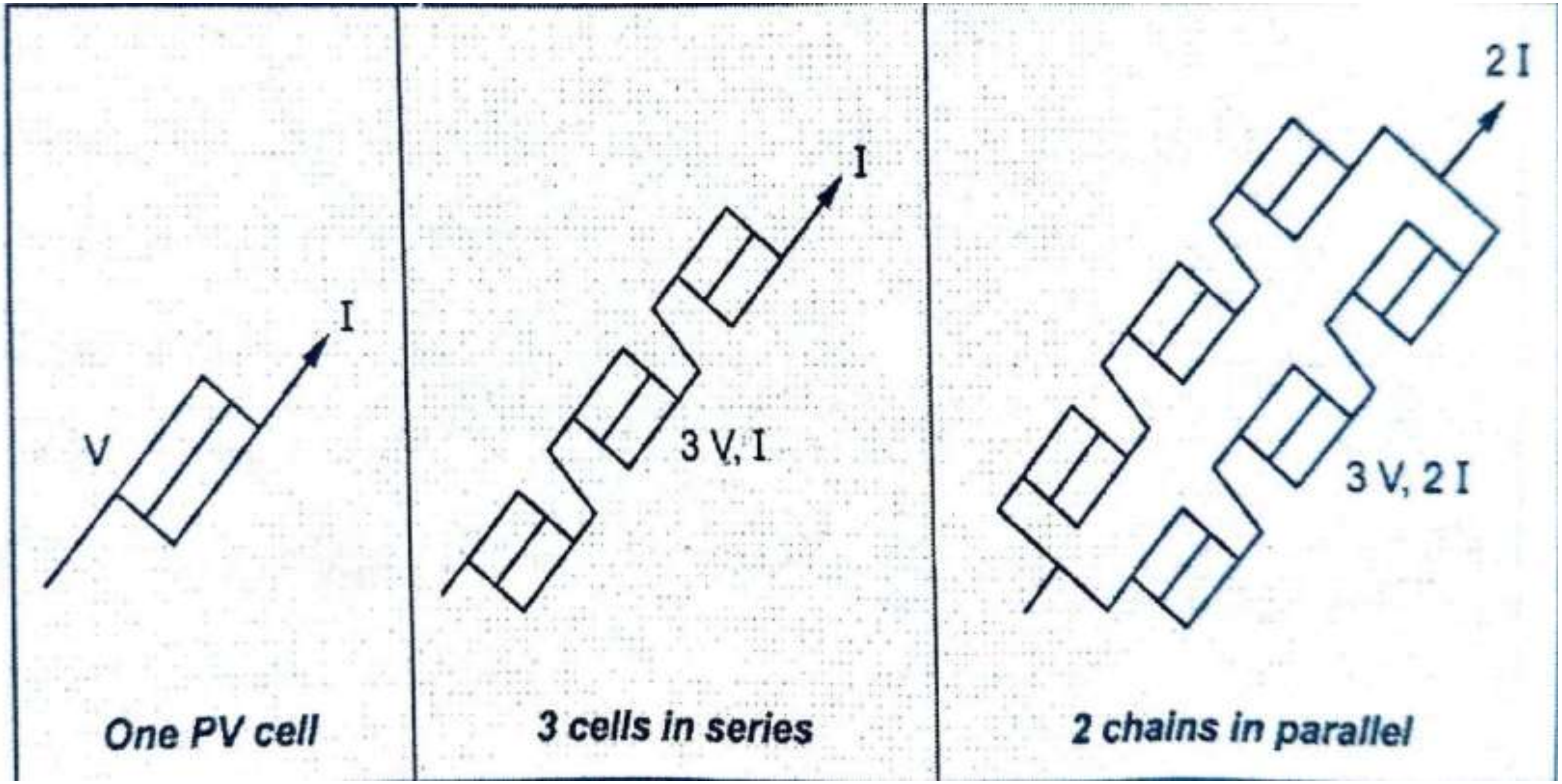
- **Fuel cells eliminate pollution caused by burning fossil fuels, the only by- product is water.**
- **The maintenance of fuel cells is simple since there are few moving parts in the system.**
- **Use variety of fuels, renewable energy and clean fossil fuels.**
- **Fuel cells can be responsive to changing electrical loads.**
- **Fuel cells provide high quality DC power.**

Disadvantages

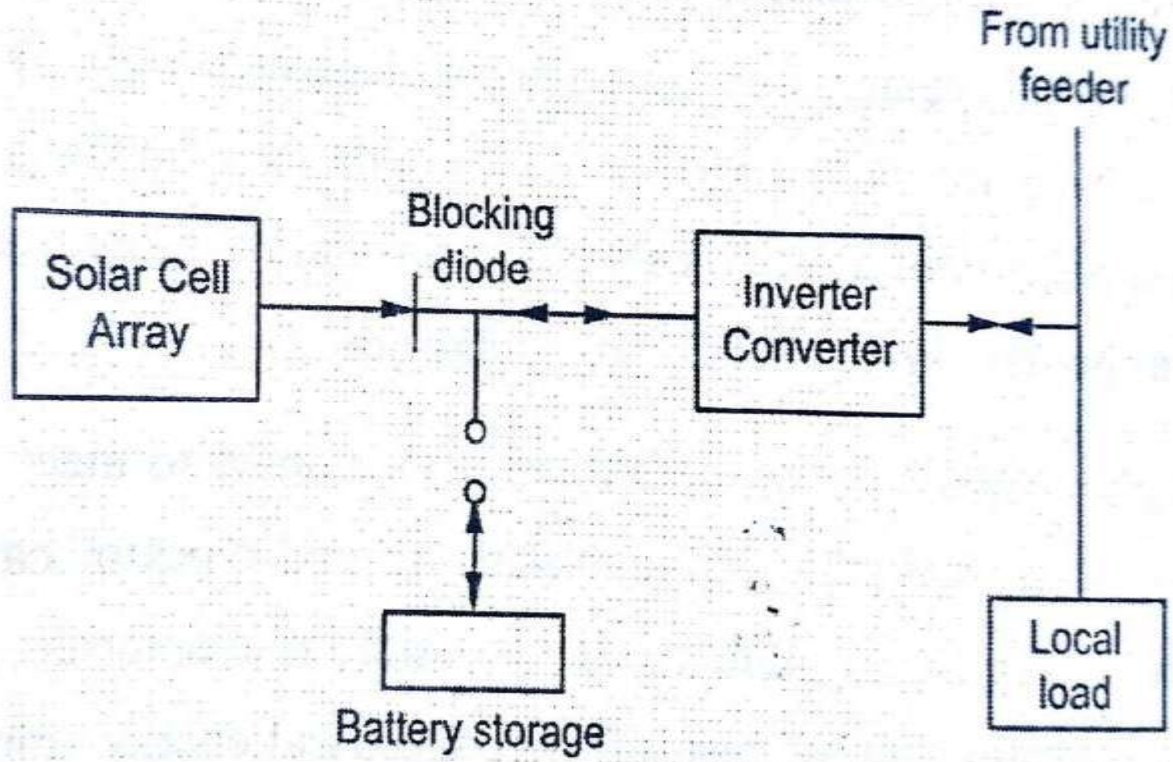
- **Initial cost is high & fuel cells are currently very expensive to produce since most units are hand made.**
- **Service life is low. Operation requires frequent fuel supply.**
- **The technology is not yet fully developed and few products are available**

SOLAR ENERGY

Solar PV cell



Solar PV power generation system



SOLAR ENERGY

The collectors receives the heat from solar rays and transfer to the fluid

Two types of collectors,

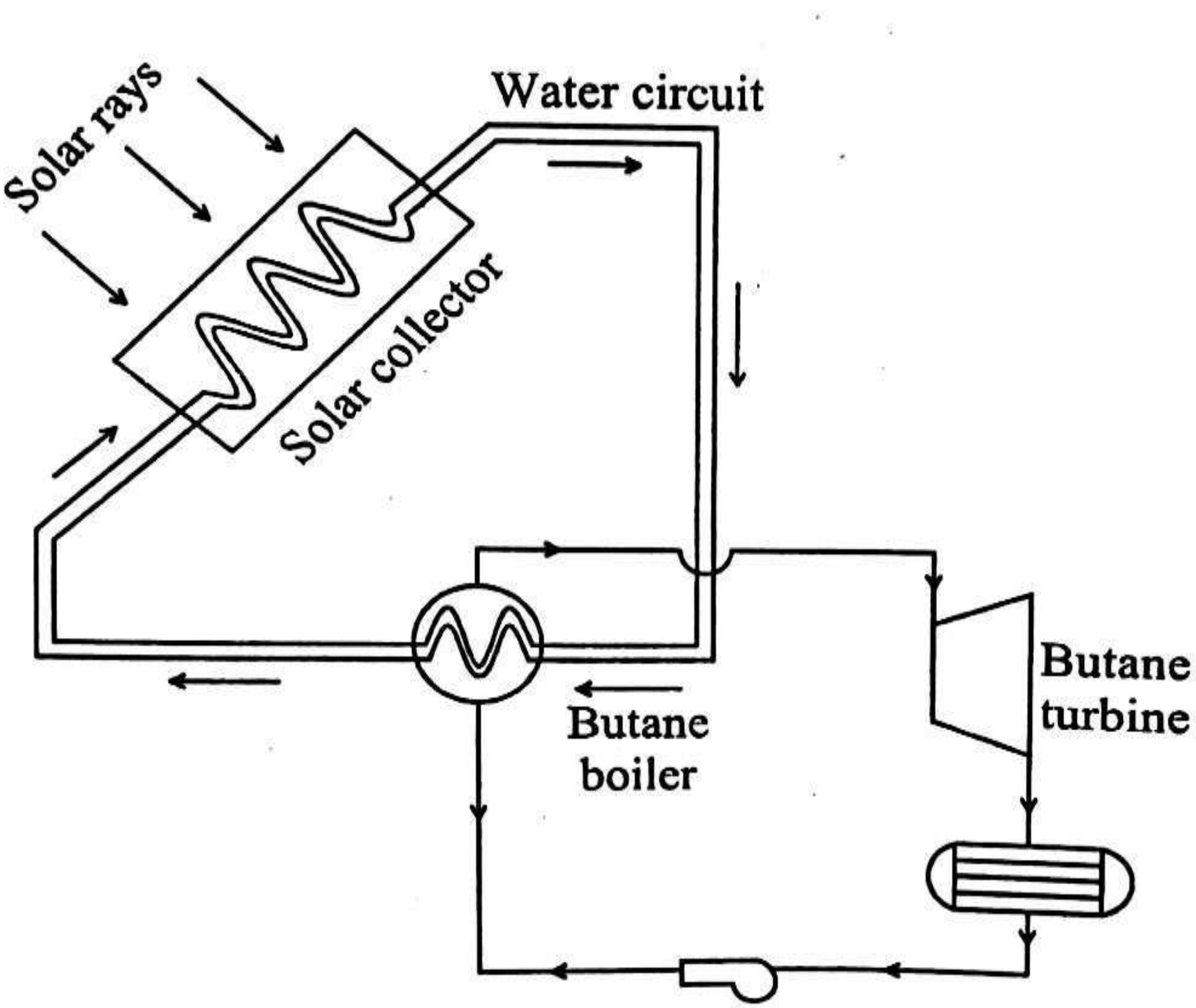
1.Flat plate (or) Non concentration collector

2.Focusing (or) Concentration collector

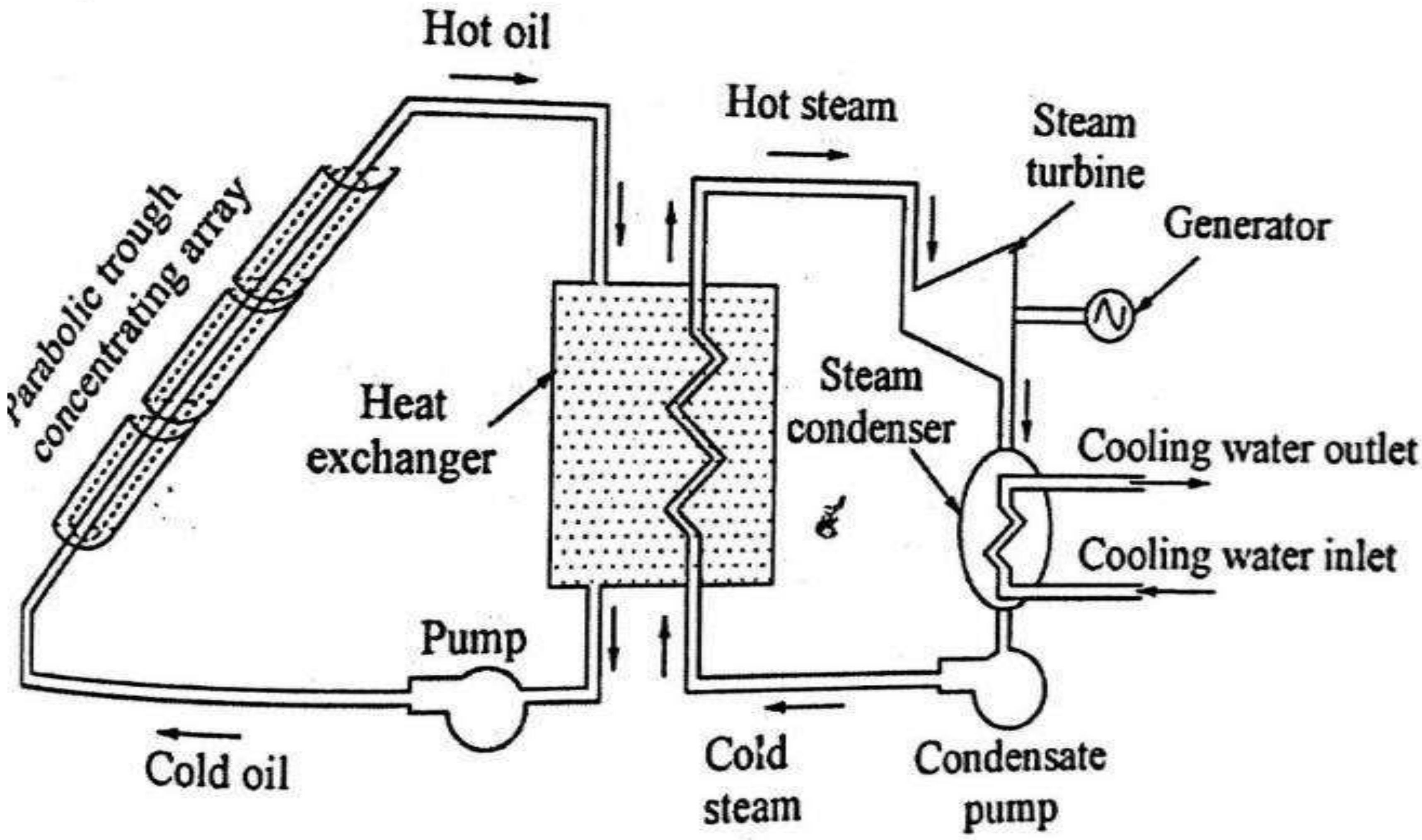
Features Of Collectors

- **Type of collectors**
- **The temperature of working fluid (Low (or) Medium(or) High)**
- **Cost of solar collector**
- **Design of solar collector system**

Flat Plate Collector



Focusing Collector



Types of concentrating collectors:

- **Parabolic trough collector**
- **Mirror strip collector**
- **Fresnel less collector**
- **Flat plate collector with adjustable mirrors**
- **Compounded parabolic concentrator**

Application

1. **Heating water**
2. **Cooking**
3. **Boiling water, which may intern be used for producing power**

IAE –II

UNIT- III

1. Chain reaction & types
2. Components of reactor
3. Working of BWR
4. Working of PWR
5. Working of FBR
6. Working of CANDU type reactor
7. Working of Gas cooled reactor (Refer note)
8. Uranium Enrichment

IAE –II

UNIT- IV

1. Essential components (or) Layout of Hydro power plant
2. Pumped stored power plant (Refer note)
3. Working of Pelton wheel
4. Tidal Energy & Types
5. Geo thermal Energy & Types (Refer note)
6. Bio gas power plant & Types
7. Solar PV power generation system
8. Type of solar power generation
9. Fuel cell & Types
10. Wind energy& Types

UNIT - V

ENERGY, ECONOMIC & ENVIRONMENTAL ISSUES OF POWER PLANTS

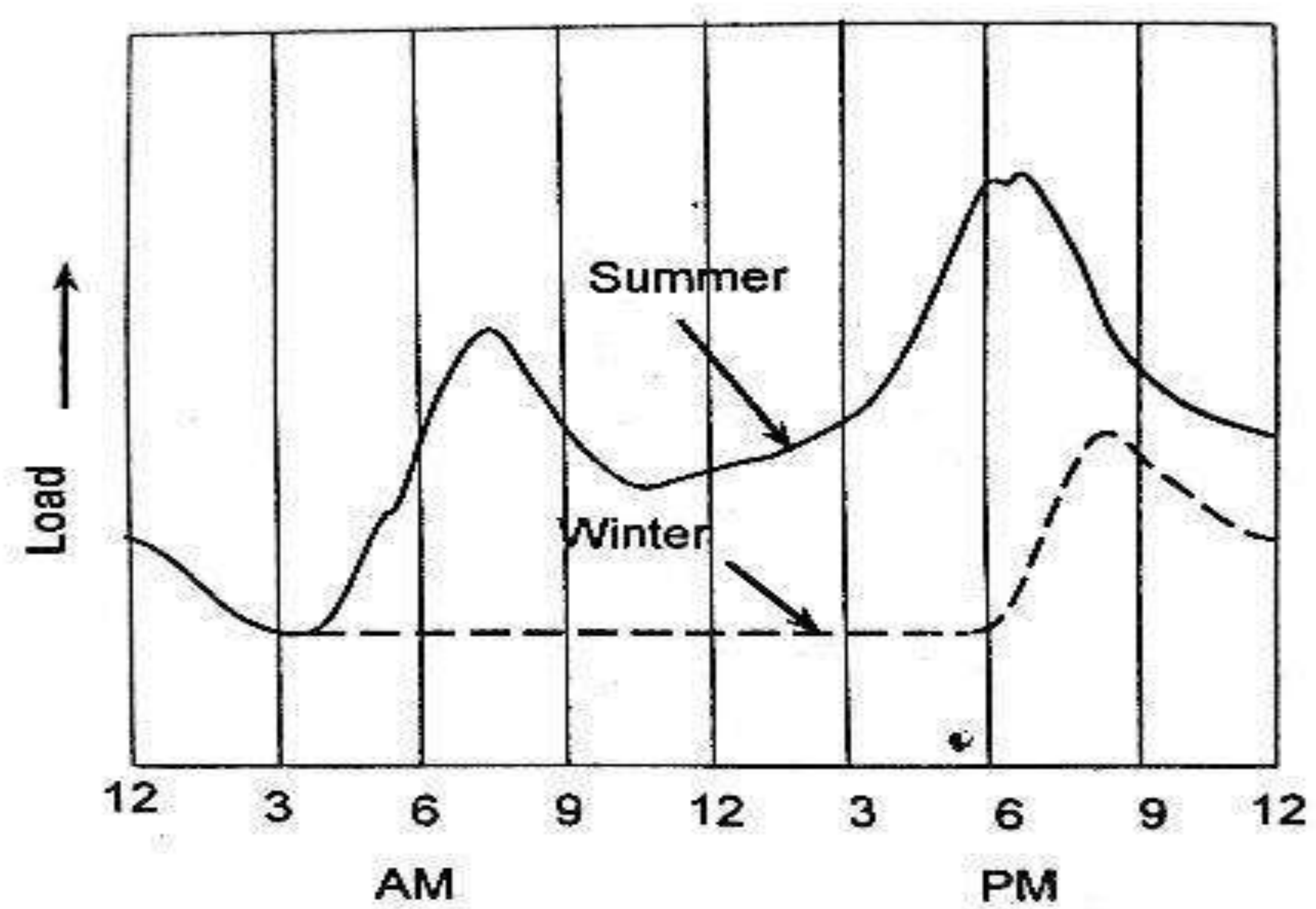
Load Curve

- It is a graphical representation which shows power demands for every instant during a certain time period
- It is drawn between Load(KW) and Time(Hr's)
- If it is plotted for 1 hour, it is hourly load curve
- If it is plotted for 24 hours, it is daily load curve
- If it is plotted for One years, it is Annual load curve

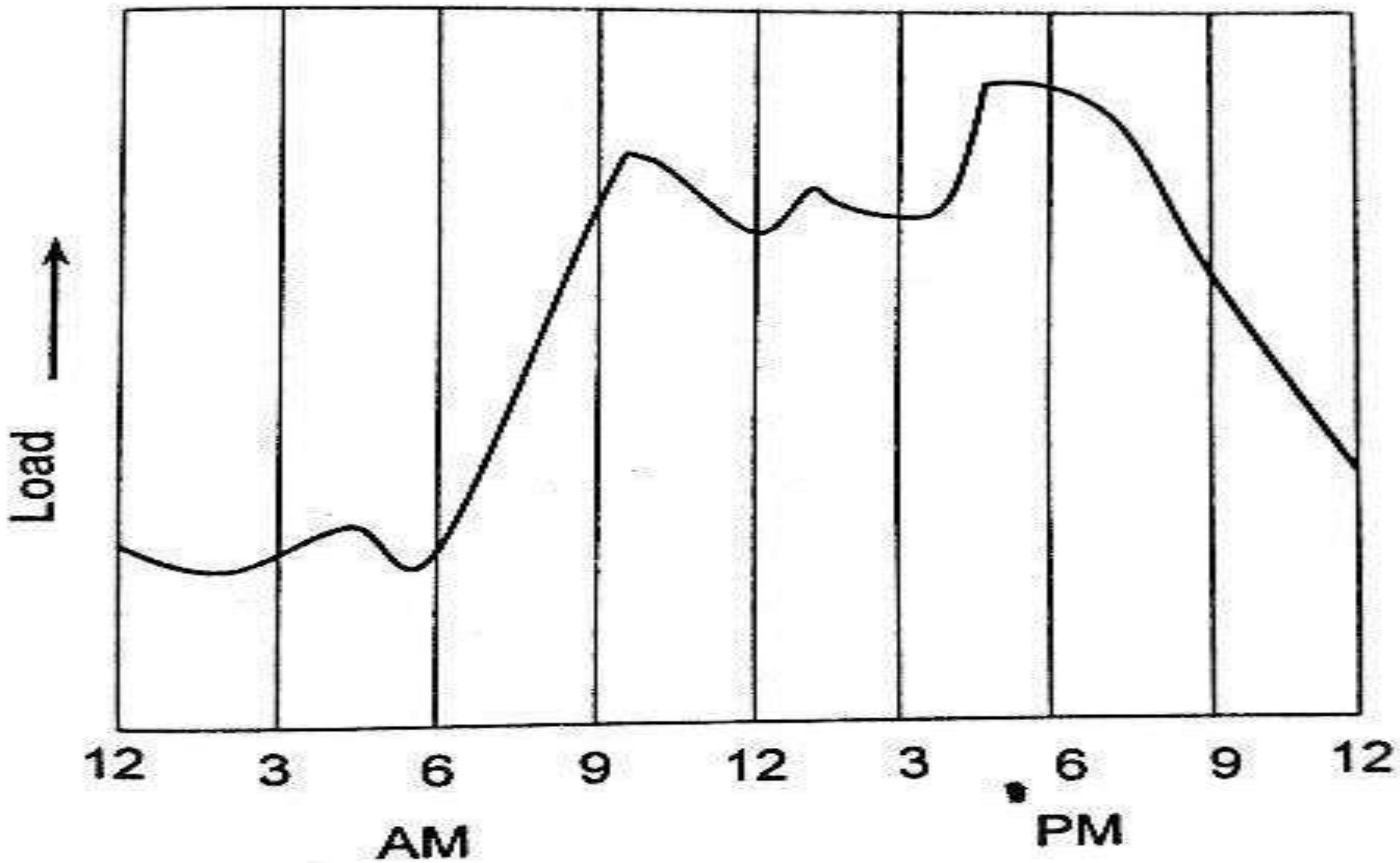
Load Distribution Parameters

- Residential Load
- Commercial Load
- Industrial Load
- Municipal Load
- Irrigation Load
- Traction Load

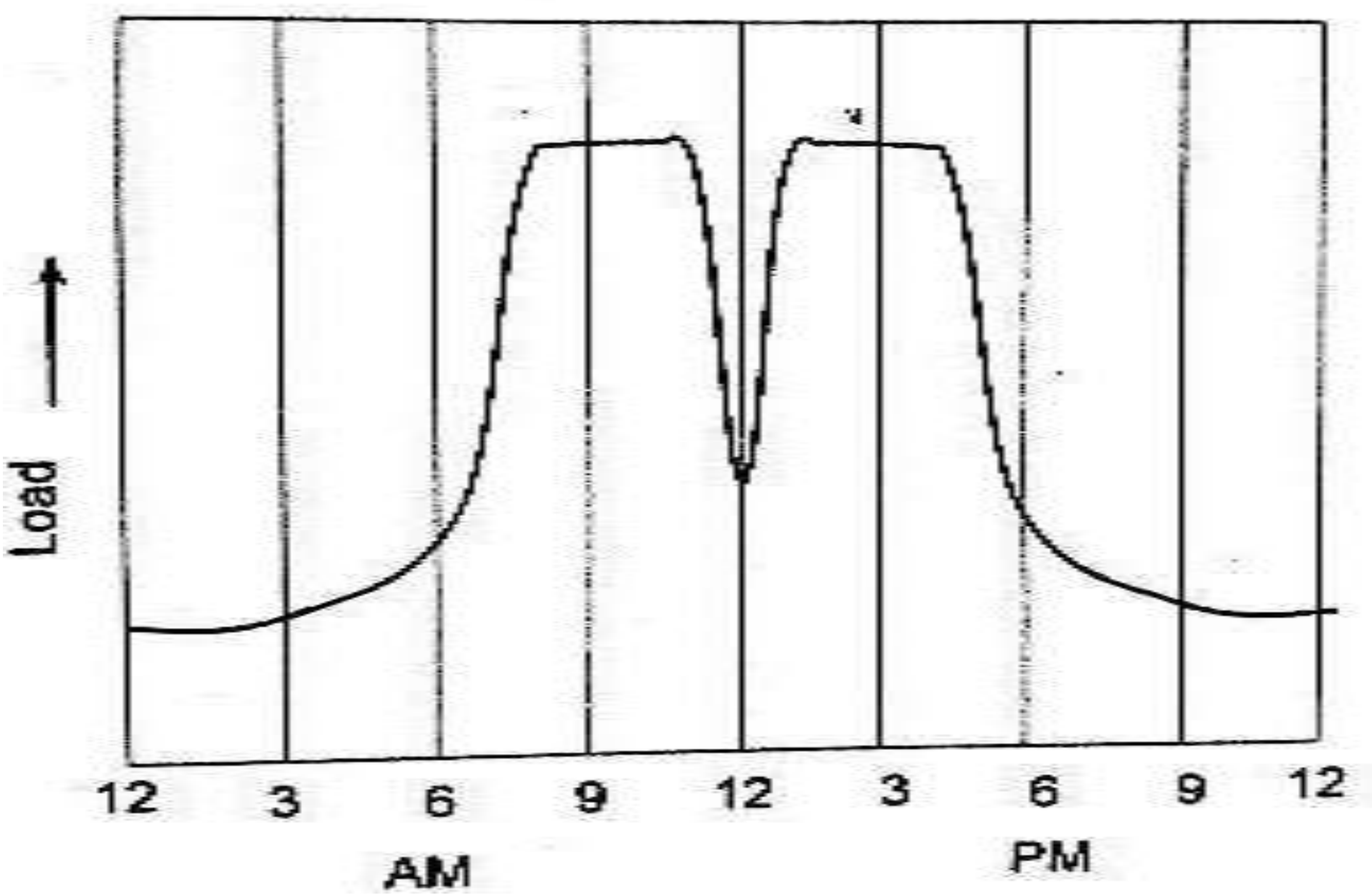
1. Residential Load Curve



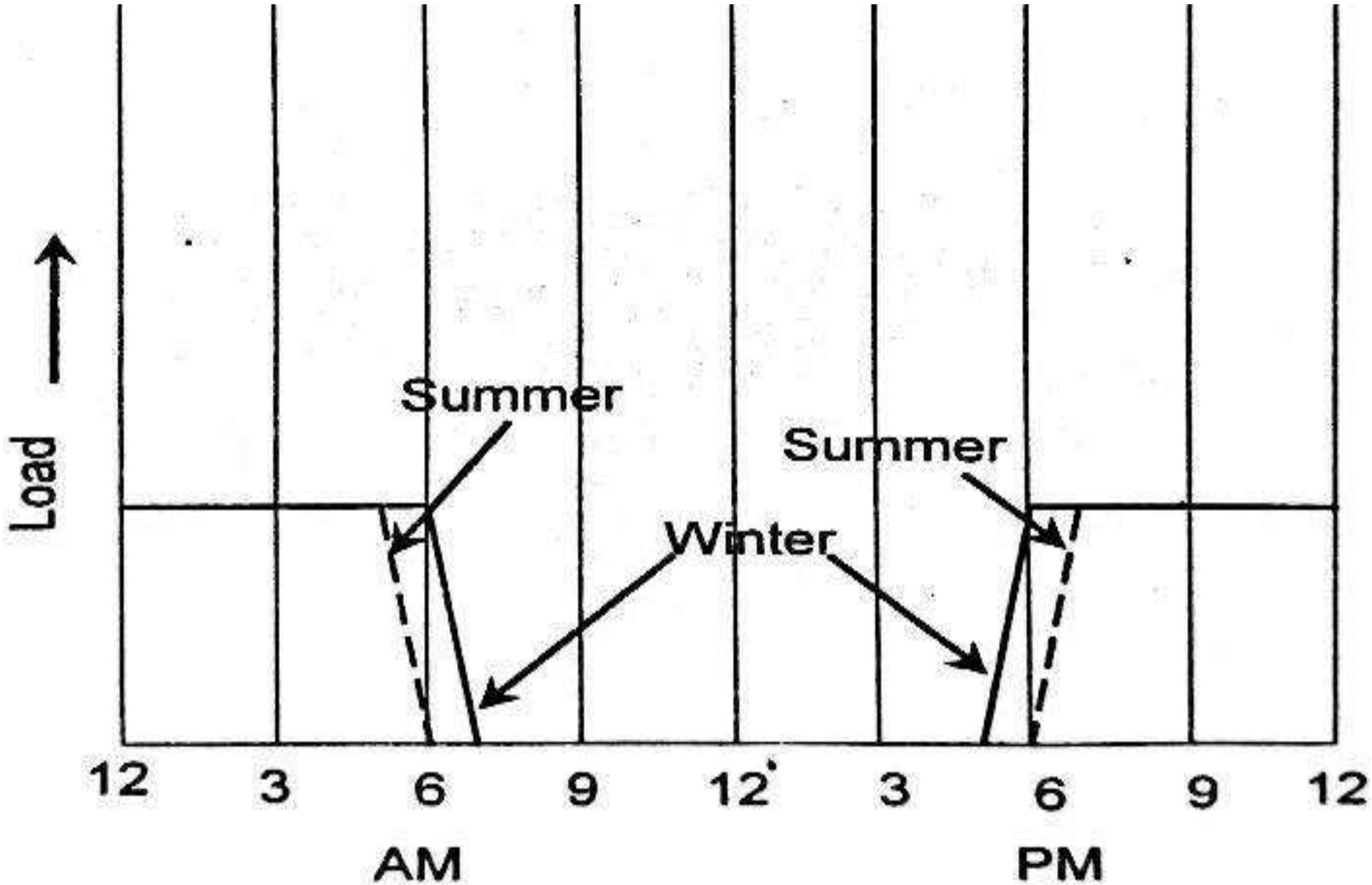
2. Commercial Load Curve



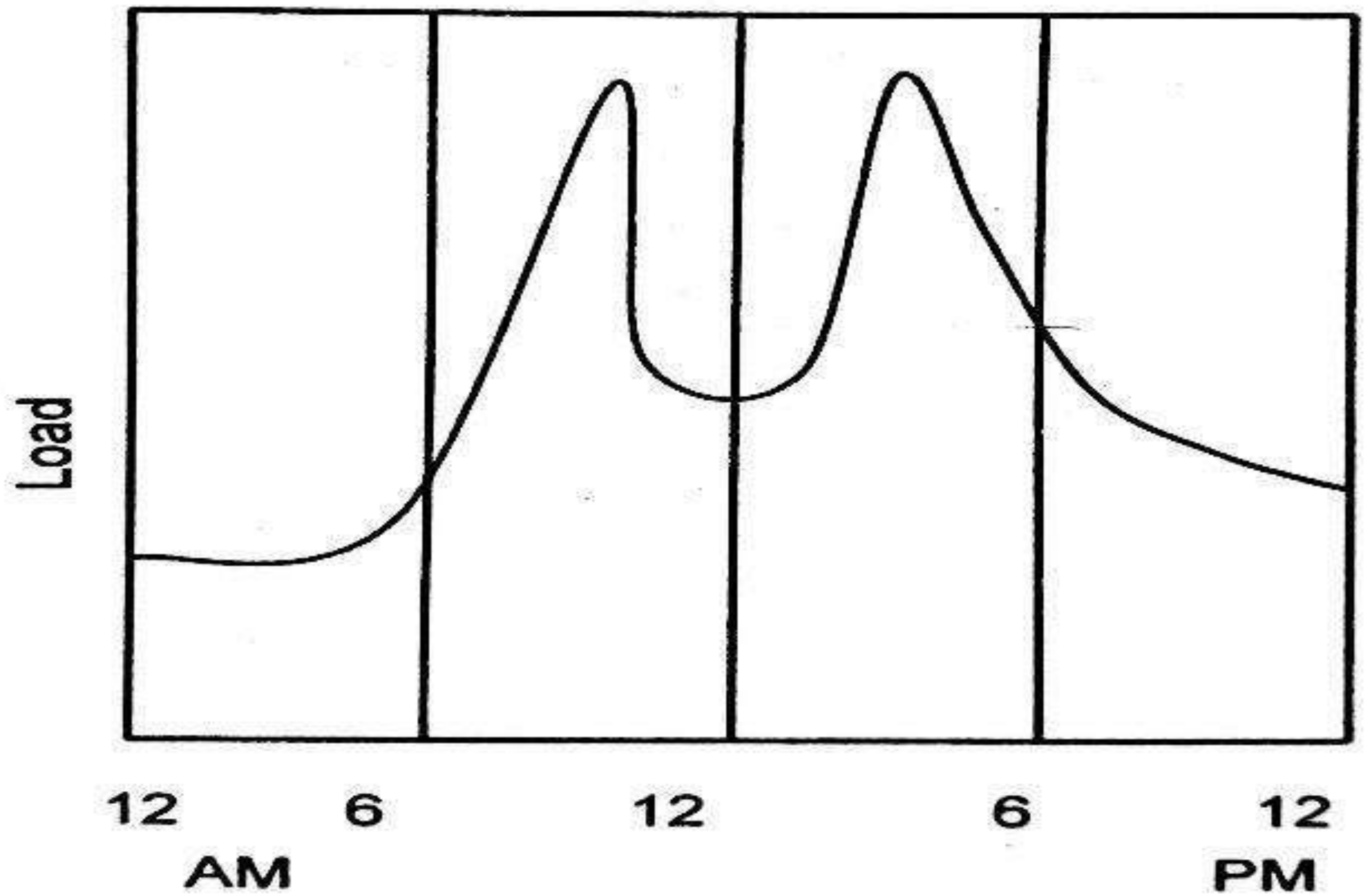
3. Industrial Load Curve



4. Street Light Load Curve



5. Urban Traction Load Curve



Important Terms:

1) Connected Load

2) Demand

3) Maximum demand

4) Demand Factor = $$\frac{Maximum\ (or)\ Peak\ demand}{Total\ connected\ Demand}$$

5) Load Factor = $$\frac{Average\ Load}{Peak\ Load\ (or)\ maximum\ demand}$$

6) Capacity Factor

$$= \frac{Average\ load}{Plant\ Capacity} = \frac{E}{C\ x\ t}$$

Where, E = Energy produced(kWhr)

C = Capacity of the plant (kW)

t = Total No of hr's

7) Utilization Factor = $\dfrac{Maximum\ Load}{Rated\ Capacity\ of\ the\ plant}$

8) Reserve Factor = $\dfrac{Load\ Factor}{Capacity\ Factor}$

8) Diversity Factor = $\dfrac{Sum\ of\ the\ individual\ maximum\ demand}{Annual\ peak\ load}$

TARIFF (or) ENERGY RATE

Objectives of tariff:

- **Recovery of cost of capital investment in generating equipment, transmission and distribution system**
- **Recovery of the cost of operation, supplies and maintenance of the equipment**
- **Recovery of the cost of material, equipment, billing and collection cost as well as for miscellaneous services**
- **A net return on the total capital investment must be ensured**

Requirements Of Tariff

- **It should be easier to understand**
- **It should provide low rates for high consumption**
- **It should be uniform over large population**
- **It should encourage the consumers having high load factors**
- **It should take into account maximum demand charges and energy charges**
- **It should provide incentive for using power during off-peak hours..etc**

General Tariff Form

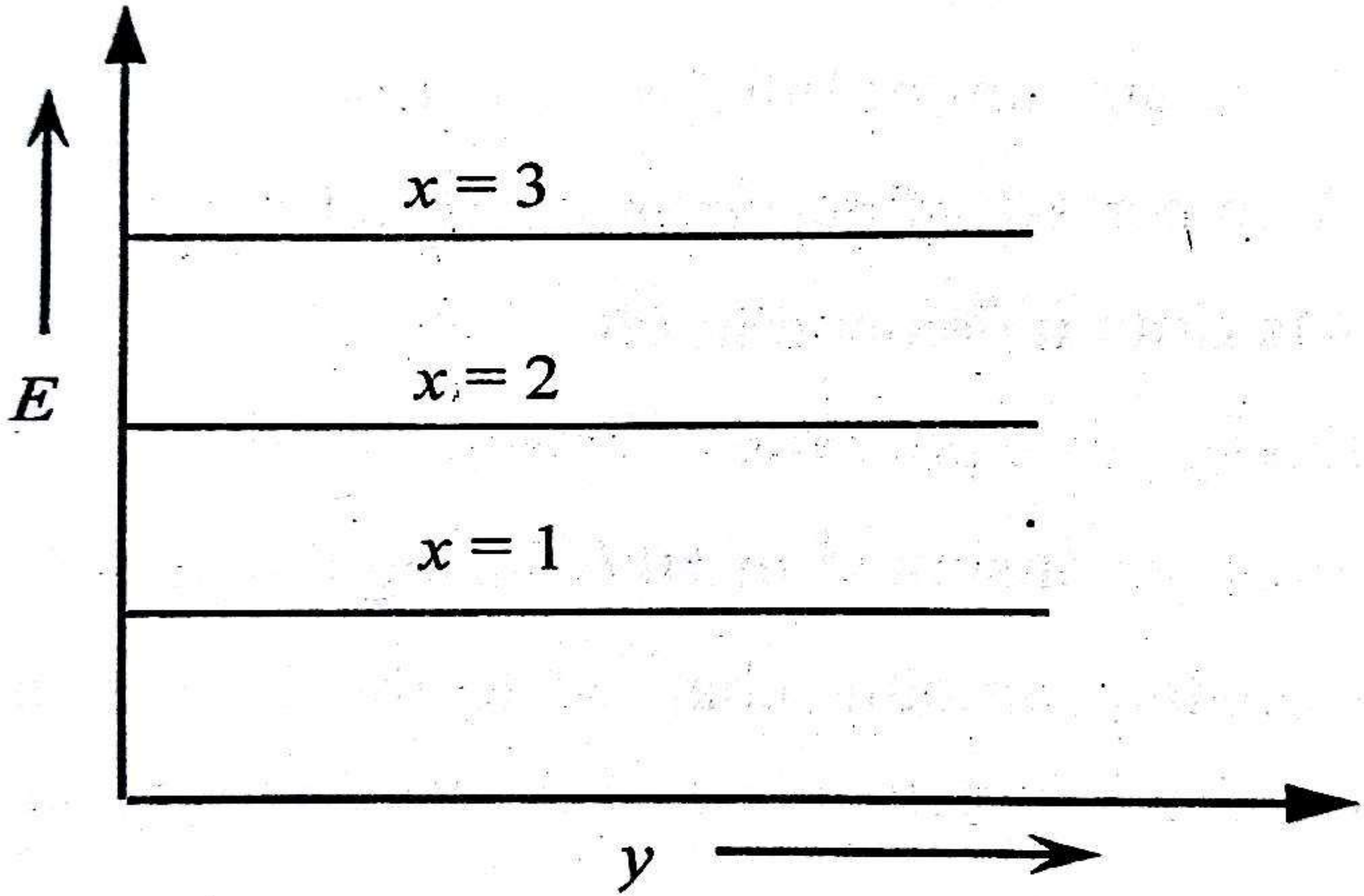
- **A large number of tariff forms have been framed time to time and are in use. All these different types are derived from the following general equation.**

$$Z = A \times X + B \times Y + C$$

Types Of Tariffs

1. **Flat demand rate**
2. **Straight line meter rate**
3. **Block-meter rate**
4. **Hopkinson or Tow-part tariff**
5. **Doherty or Three-part tariff**

1. Flat demand rate



$E = AX$

E = Total amount of bill for the period considered

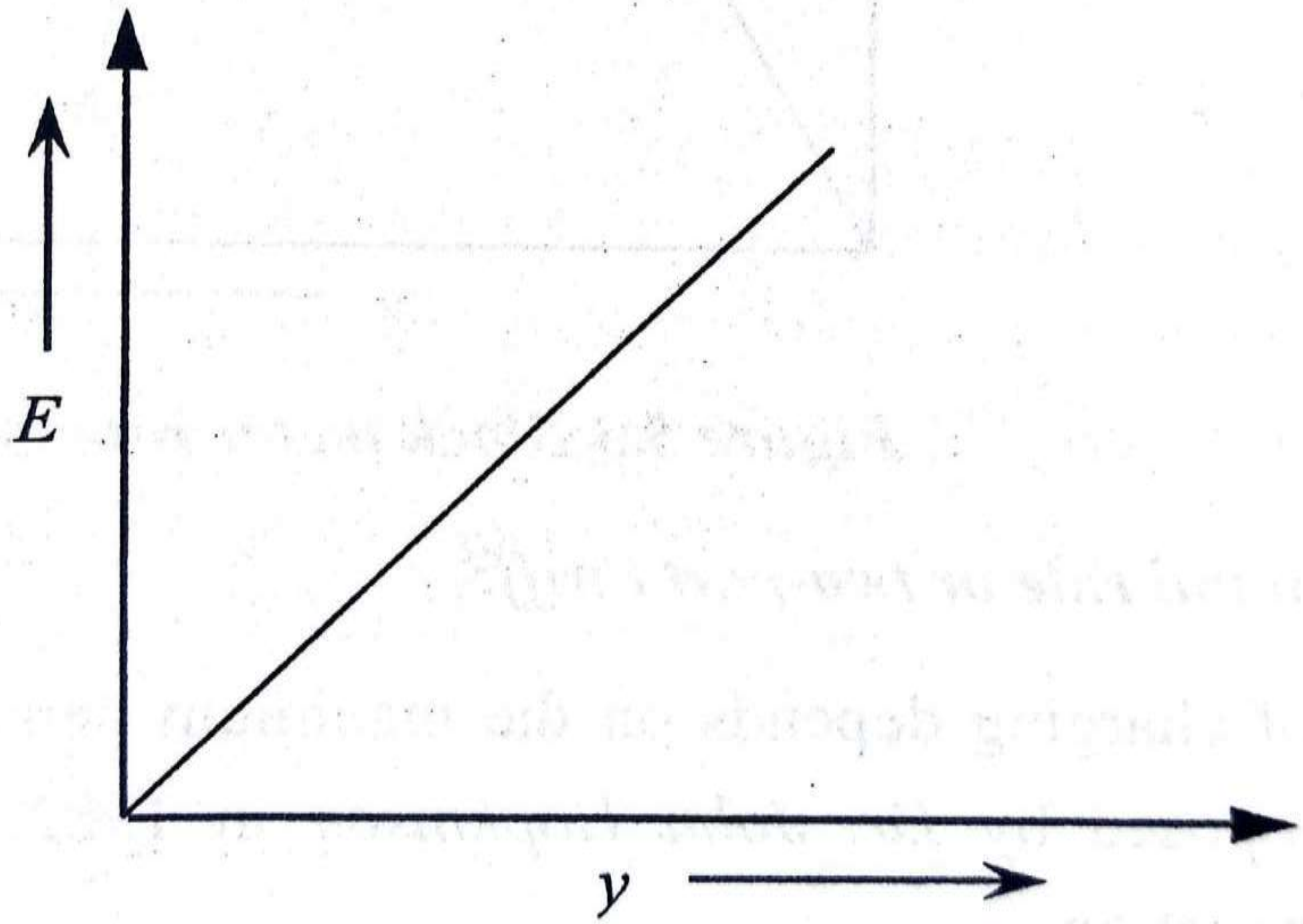
A = Rate per KW of maximum demand

X = Maximum demand in KW

Application:

1. **Signal system**
2. **Street Lighting**
3. **Irrigation tube well**

2. Straight line meter rate



E = B Y

E = Total amount of bill for the period considered

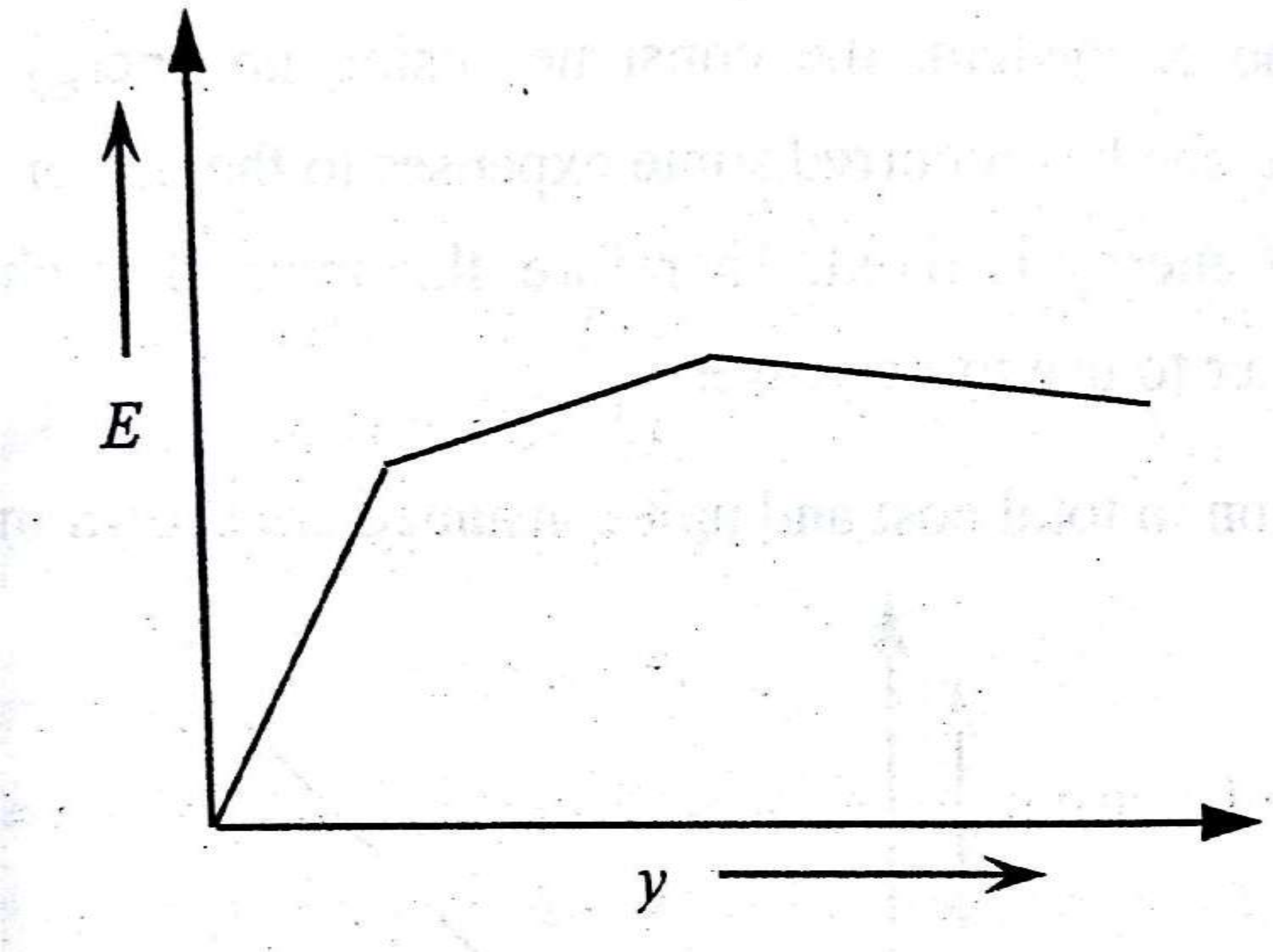
B = Energy rate per KWh

Y = Energy consumed in KWh during the period

Application:

1. **Residential**
2. **Commercial**

3. Block-meter rate



E1 $= B_1Y_1 + B_2Y_2 + B_3Y_3 + \dots$

Where,

$Y_1 + Y_2 + Y_3 + \dots\dots = Y$ **(Total energy consumption)**

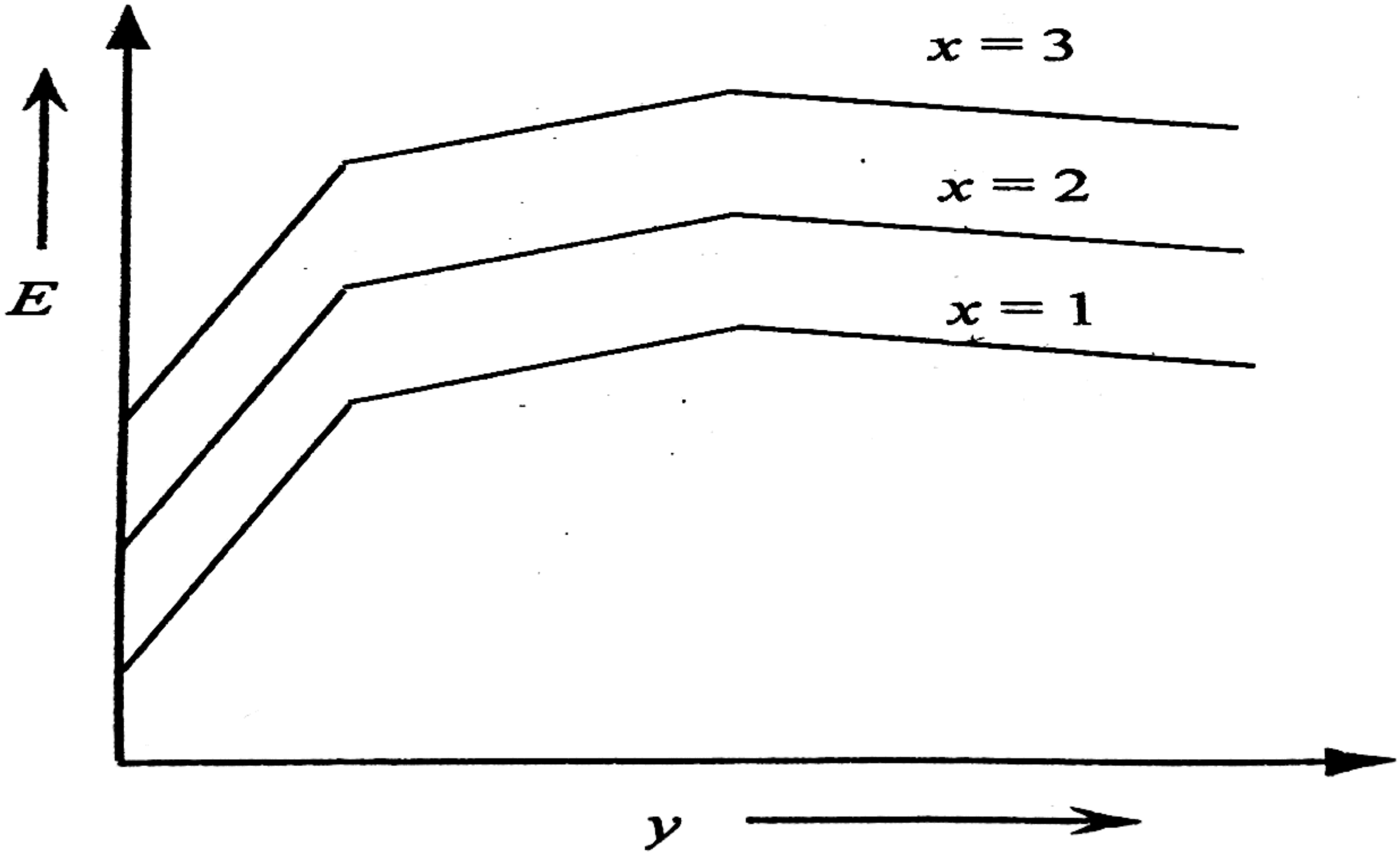
B1,B2&B3 are unit charges

B3 < B2 < B1

Application:

1. **Residential**
2. **Commercial**

4. Hopkinson (or) Tow-part tariff



E = A + BY

E = Total amount of bill for the period considered

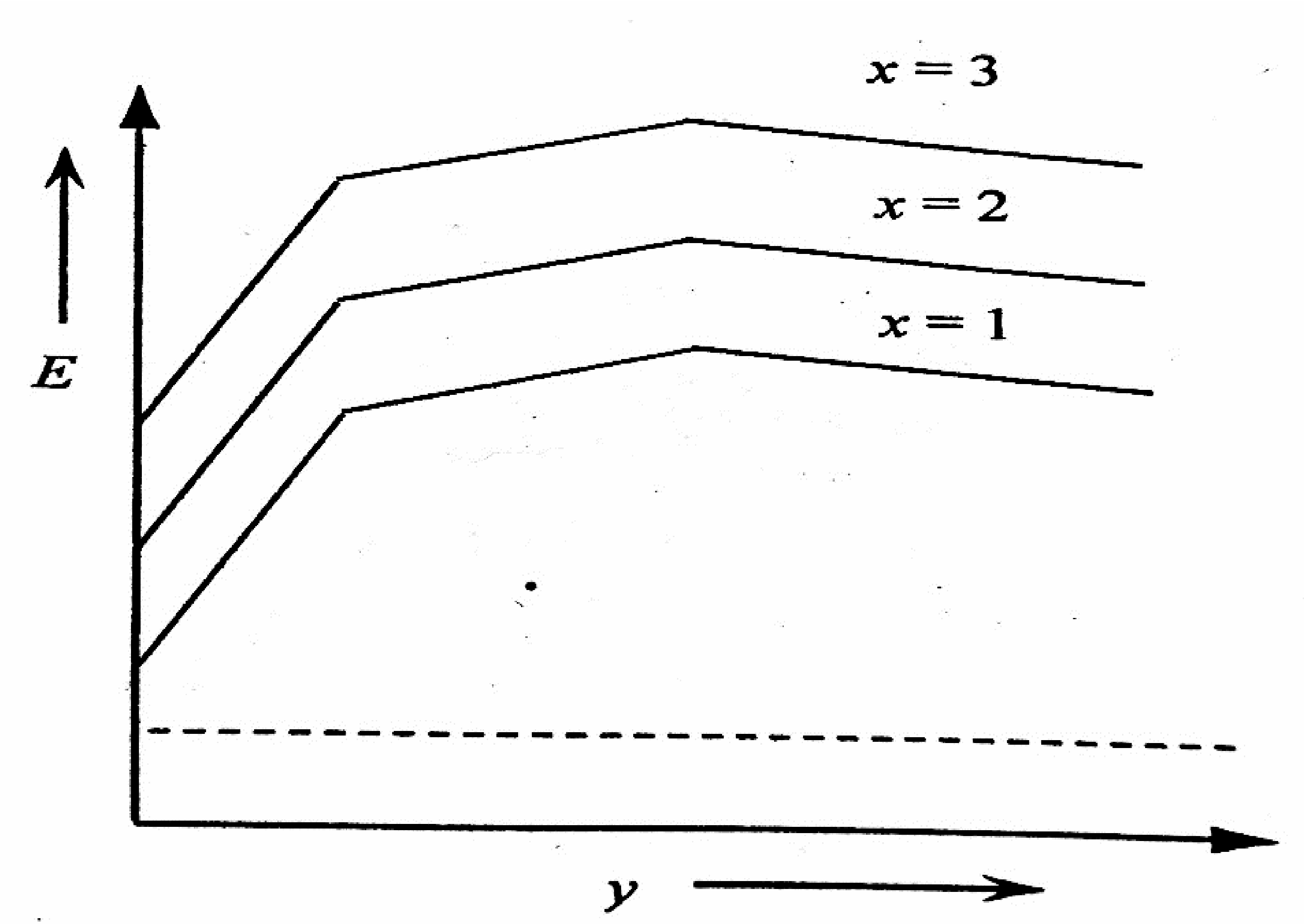
B = Energy rate per KWh

Y = Energy consumed in KWh during the period

Application:

1. Industrial

5. Doherty or Three-part tariff



$E = AX + BY + C$

Where,

E = Total amount of bill for the period

A = Rate per KW of maximum demand

X = Maximum demand in KW

B = Energy rate per KWh

Y = Energy consumed per KWh

C = Constant amount charged

Application:

1. Industrial

Nuclear Waste Disposal

Types of Nuclear Waste,

a) On the basis of half-life time

i) Fission products

ii) Actinides

iii) The neutron activation products

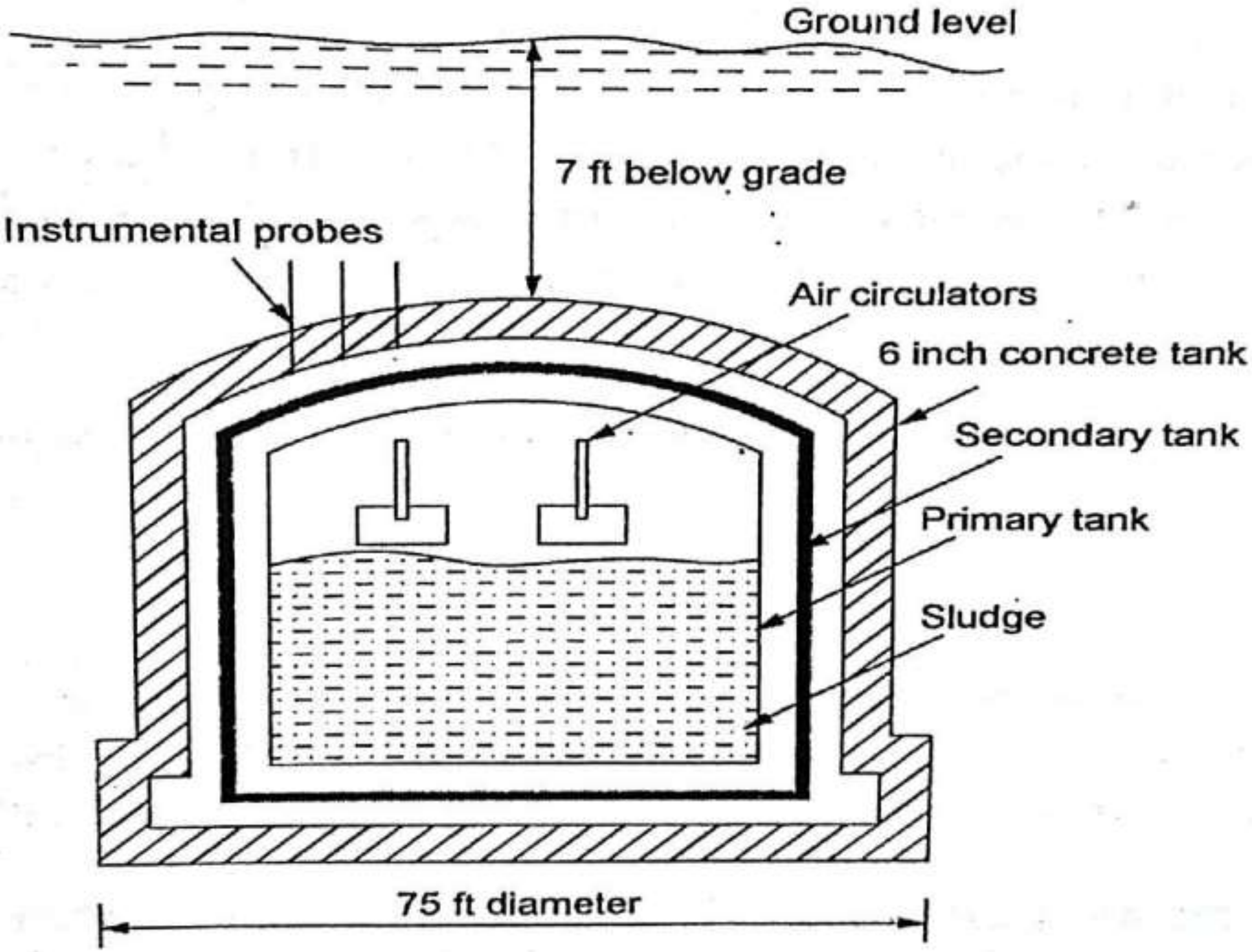
b) On the basis of the intensity of radiation

i) Low level waste

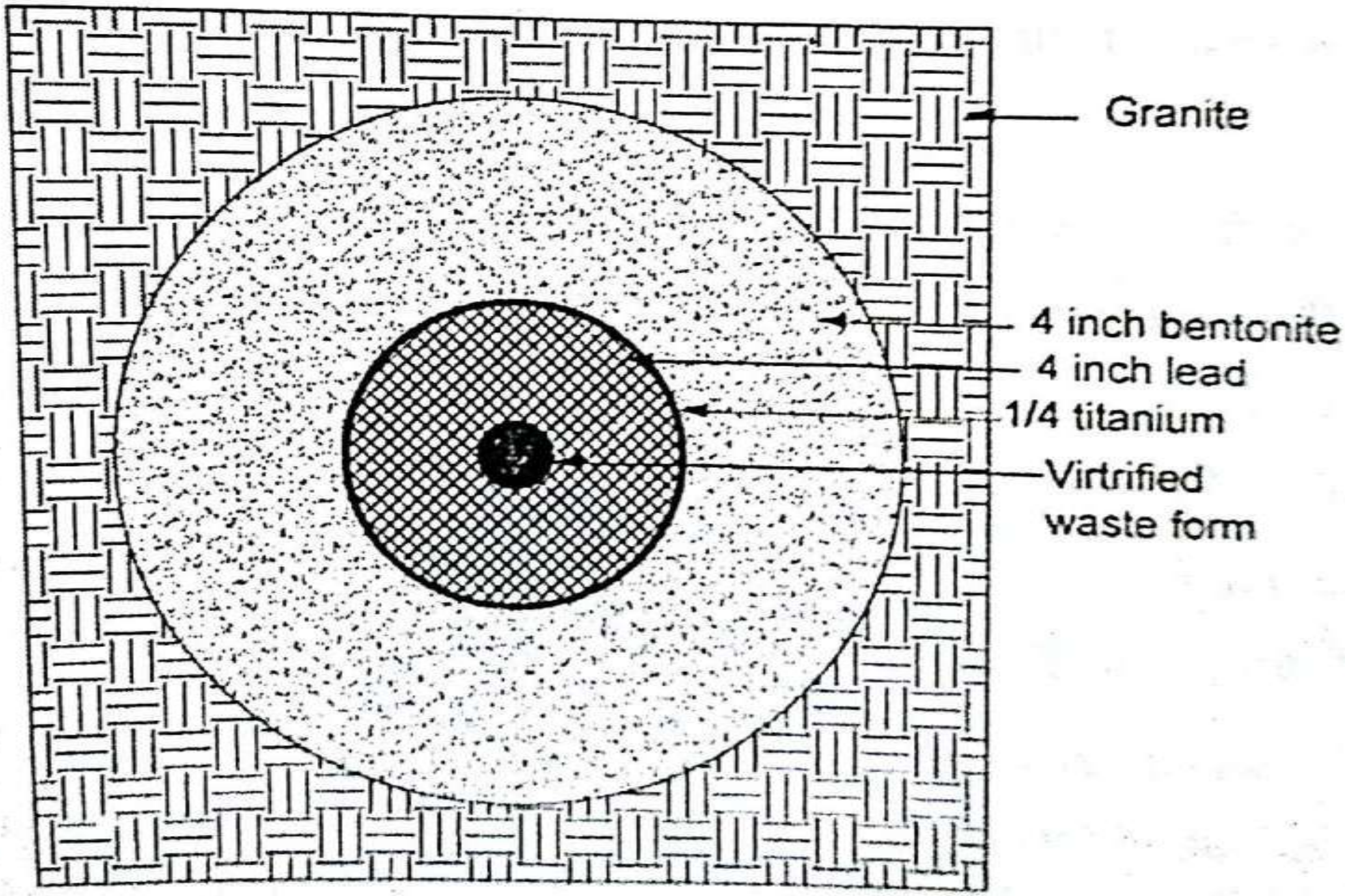
ii) Medium level waste

iii) High level waste

Disposal of Low level solid waste



Underground Disposal of High level waste



Thermal Power plant Waste Disposal

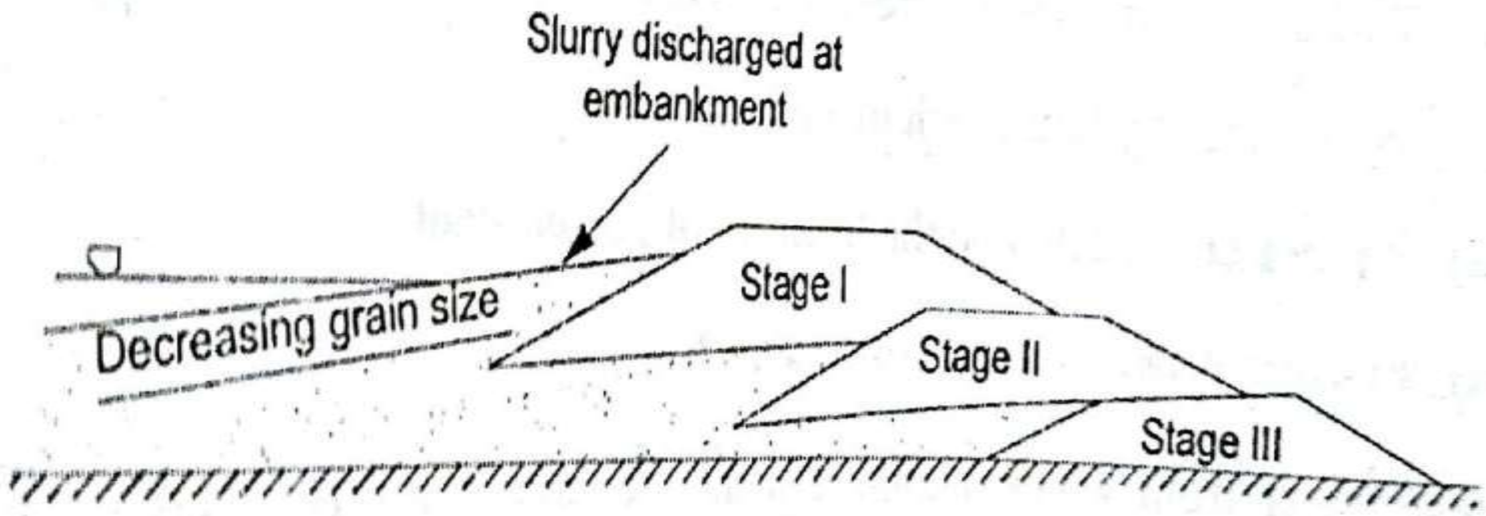
Methods,

1) Upstream Method

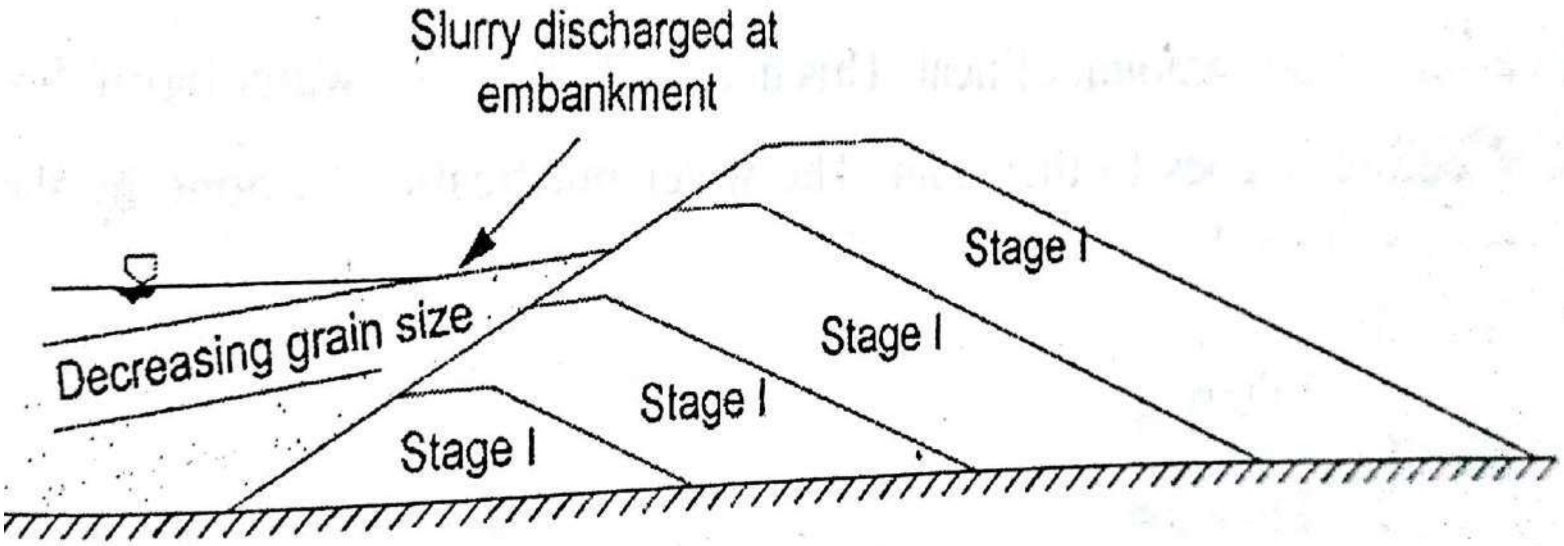
2) Downstream Method

3) Centerline Method

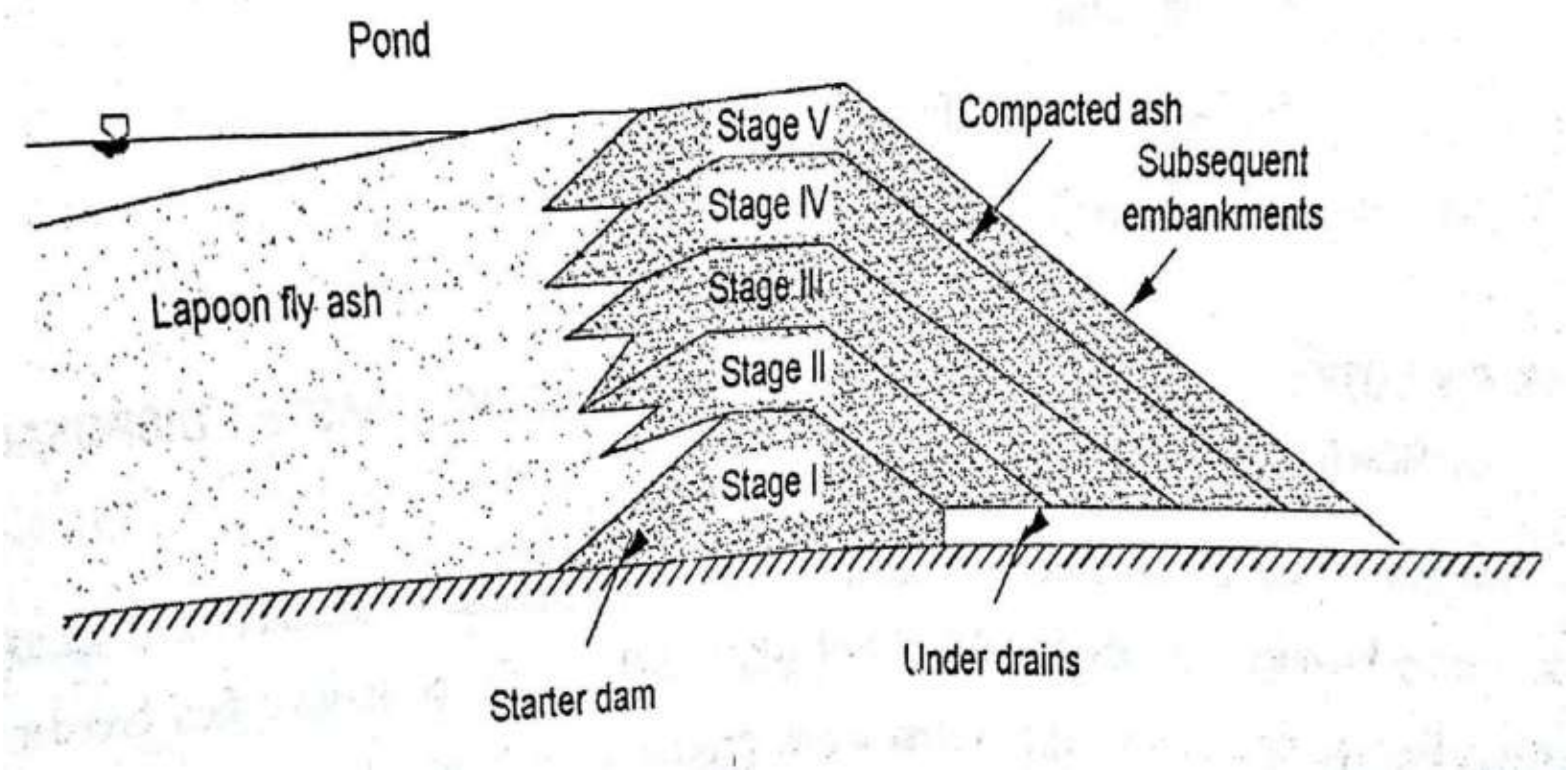
a) Upstream Method



b) Down stream Method



c) Center line Method



Pollution Control Technology

Emissions can be classified into four types,

1. **Gaseous emission**
2. **Particulate emission**
3. **Solid waste emission**
4. **Thermal pollution**

1. Gaseous Emission

a) Sulphur dioxide (SO_2)

b) Nitrogen oxides (NO_x)

c) Hydrogen Sulphide

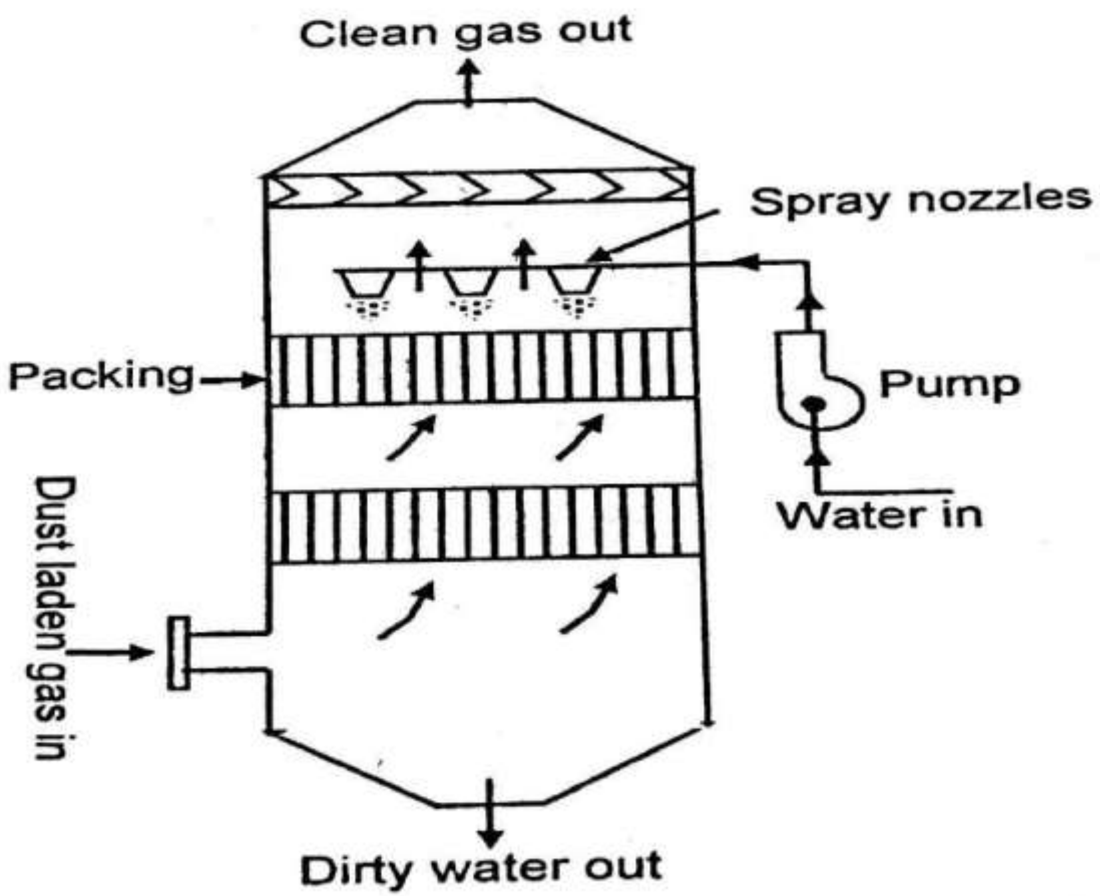
d) Carbon Monoxide (CO)

Effect of pollutants

S. No	Pollutant	On man	On vegitation	On materials/ animals
1.	SO_2	Suffocation, irritation of throat and eyes,respiration system	Destruction of sensitive crops and reduced yield	Corrosion
2.	NO_2	Irritation, bronchitis, oedema of lungs.	—	—
3.	H_2S	Bare disease, respiratory diseases.	Destruction of crops.	Flourosis in cattle grazing.
4.	CO	Poisoning, increased accident-liability	—	—

1. Removal of SO_2

- **SO2 is removed by wet scrubber and separate the particular matters**



Application of Wet scrubber

1) Chemical Industry

2)Grain milling industry

Emission of NOx:

Air + fossil fuel $\longrightarrow$ NO2

The resulting mixture is represented by NOx

Methods are used to reduce NOx emission,

- **Reducing of residence period in combustion zone**
- **Reducing of temperature in combustion zone**
- **Increase in equivalence ratio in combustion chamber**

2. Particulate emission

The particular matters are,

1) Dust(1 micron) Which do not settle down

2)Particles (10 microns) which settle down to the ground

Particles can be classified,

a) Smoke (less than 10 micron)

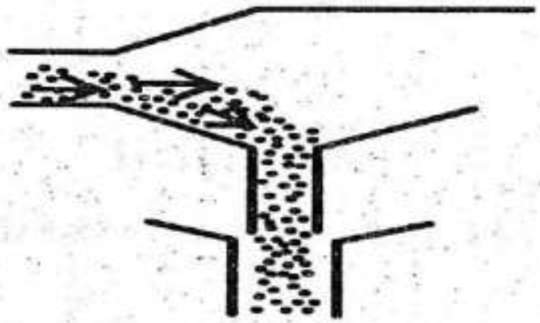
b) Fumes

These are very small particles which is obtained from chemical reaction

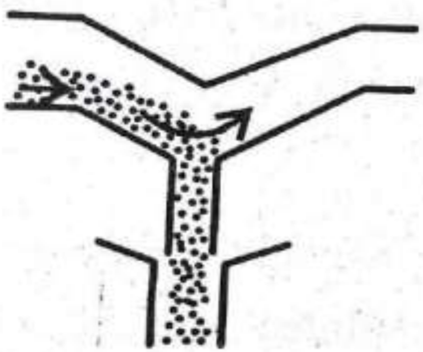
c) Fly- ash (equal to 100 microns)

d) Cinders (more than 100 microns)

Cinders,



Sudden decrease in gas velocity



Sudden change in the direction of the flow of flue gas

PROBLEMS

1) The peak load on a thermal power plant is 75 MW. The loads having maximum demands of 35MW,20MW,15MW and 18MW are connected to the power plant. The capacity of the power plant is 90MW and the annual load factor is 0.53. Calculate: a) Average load on the power plant b) Energy supplied per year c) Demand factor d) Diversity factor

Solution:

a) Load factor = $\frac{Average\ Load}{Peak\ Load}$

$$0.53 = \frac{Average\ Load}{75}$$

Average load = 0.53 x 75

= 39.75 MW

b) Energy supplied per year = Average Load x 24 x 365

= 39.75 x 8760

= 348210 MW hr

c) Demand Factor = $\dfrac{\textit{Annual Peak Poad}}{\textit{Sum of the individual peak Load}}$

$$= \frac{75}{35+20+15+18}$$

$= \mathbf{0.852}$

d) Diversity factor = $\dfrac{\textit{Sum of the individual peak Load}}{\textit{Annual peak Load}}$

$$= \frac{35+20+15+18}{75}$$

$= \mathbf{1.173}$

2) The yearly duration curve of a certain plant can be considered as a straight line from 400 MW to 100 MW. Power is supplied with one generation unit of 250MW capacity and two units of 125 MW capacity each. Determine: a) Installed capacity b) Load factor c) Capacity factor d) Maximum demand e) Utilisation factor

Solution:

a) Installed capacity

$$= 1 \times 250 + 2 \times 125$$

$$= 500 \text{ MW}$$

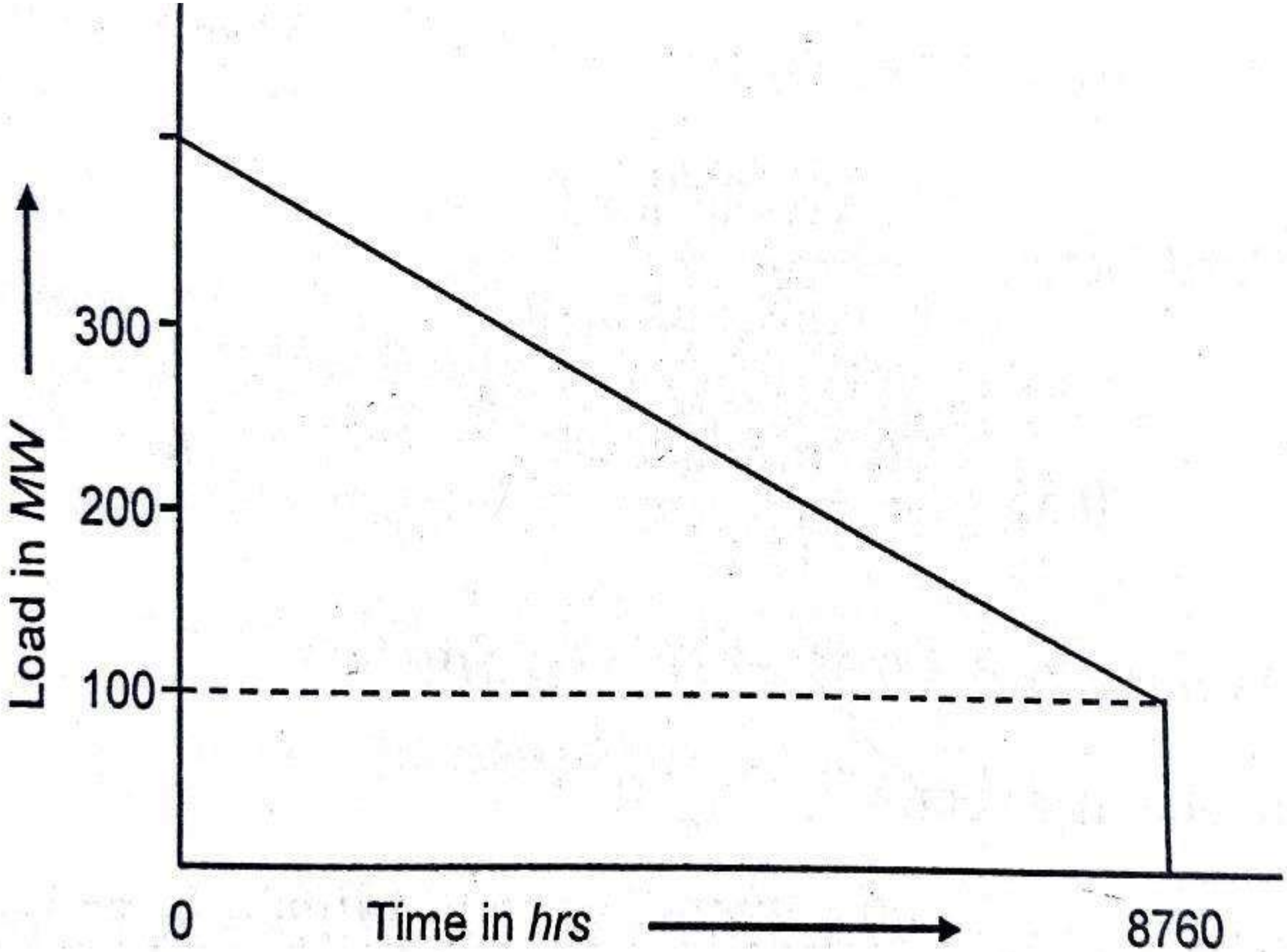
b) Load factor

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$\text{Average Load} = \frac{\text{Area under the load curve}}{\text{Number of hours in the period}}$$

For one year duration,

$$24 \times 365 = 8760 \text{ hrs}$$



Load in MW
300
200
100
0
Time in hrs
8760

Area under the load curve,

$$= 100 \times 8760 + 1/2\,(400 - 100) \times 8760$$

$$= 2190000 \text{ MW hr}$$

Average Load $= \dfrac{2190000}{8760} = 250 \text{ MW}$

Load factor $= \dfrac{\text{Average Load}}{\text{Maximum deman}} = \dfrac{250}{400} = 0.625$

c) Capacity factor $= \dfrac{\text{Average Load}}{\text{Plant capacity}} = \dfrac{250}{500} = 0.5$

d) Maximum demand = 400 MW

e) Utility factor $= \dfrac{\text{Maximum Load}}{\text{Plant capacity}} = \dfrac{400}{500} = 0.8$

3) A thermal power station consists of two 60 MW units each running for 7320 hrs a Year and one 30 MW unit running for 1800 hrs a year. The energy produced by the plant per year is 725 x 10^6 kWh. Determine the plant load factor and plant use factor. Assume that the maximum demand is equal to plant capacity.

Solution:

Total capacity of the power plant,

$$= 2 \times 60 + 30 = 150 \text{ MW} = 150 \times 10^3 \text{ kW}$$

$$\text{Average Load} = \frac{\text{Energy produced per year}}{\text{Number of hrs in the period}}$$

$$\text{Average load} = \frac{725 \times 10^6}{8760}$$

$$= 82726.56 \text{ Kw}$$

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$= \frac{82762.56}{150 \times 10^3}$$

$$= 0.552 = 55.2\%$$

Use Factor = $\dfrac{\textit{Annual energy production in given time period}}{\textit{Maximum energy production by the plant}}$

Maximum energy produced by the plant,

= (2 x 60 x 7320) + (1 x 30 x 1800)

= 932400 MW hr

= 932.4 x 10^6 kW hr

Use Factor = $\dfrac{725 \, x \, 10^6}{932.4 \, x \, 10^6}$ = **0.778**

4) The output of a generating station is 12 MW and annual load factor is 0.58. The annual cost of fuel for running the plant is Rs. 12 x 10^5 and the annual wages and taxes are Rs. 10 x 10^5. The capital cost of the plant is Rs. 700 x 10^5 and interest and depreciation charges are made 10% of the capital cost per annum. Determine the cost of generation.

Solution:

$$\text{Load factor} = \frac{\textit{Average Load}}{\textit{Maximum demand}}$$

$$0.58 = \frac{\textit{Average Load}}{12}$$

Average Load = 12 x 0.58 = 6.96 MW

Energy produced per year,

= 6.96 x (365 x 24)

= 60969.6 MW hr = 609.696 x 10^5 kWhr

Fixed cost = Cost of interest and depreciation

= 0.1 x 700 x 10^5 = Rs. 70 x 10^5

Running cost = Cost of fuel + Cost of wages and taxes

$= Rs.\ 12 \times 10^5 + Rs.\ 10 \times 10^5 = Rs.\ 22 \times 10^5$

Total cost = Fixed cost + running cost

$= Rs.\ 70 \times 10^5 + Rs.\ 22 \times 10^5 = Rs.\ 92 \times 10^5$

Cost of energy per kW hr,

$$= \frac{92 \times 10^5}{609.696 \times 10^3}$$

= Rs. 0.151

= 15.1 paise.

5) The following data pertain to a power plant Installed capacity 200= MW; Capital cost= Rs. 350 x 10^7; Annual cost of fuel, taxes and salaries= Rs. 55 x 10; Rate of interest is 5% of the capital; Rate of depreciation is 6% of the capital; Annual load factor = 0.65; Capacity factor= 0.56; Energy used in running the plant auxiliaries = 4% of total units generated. Determine the (a) cost of power generation and (b) reserve capacity.

Solution:

Load factor = $$\frac{Average\ Load}{Maximum\ demand}$$ **-----------(1)**

Capacity factor = $$\frac{Average\ Load}{Plant\ capacity}$$ **------------**
(2)

Divided by equation (1) to equation (2)

$$\frac{Load\ factor}{Capacity\ factor} = \frac{Average\ Load}{Maximum\ demand} \times \frac{Plant\ capacity}{Average\ load}$$

$$\frac{0.65}{0.56} = \frac{200}{Maximum\ demand}$$

Maximum demand = 200 x $\frac{0.56}{0.65}$

= **172.3 MW**

Reserve capacity = 200-172.3 = 27.7 MW

From equation (1),

Average load = Load factor x Maximum demand

= 0.65 x 172.3 = 112 MW

Energy produced per year

= 112 x (365 x 24)

= 981120 MW

= 981.12×10^6 kWh

Net energy delivered,

= Energy produced - Energy used in running the plant auxiliaries

$$= 981.12 \times 10^6 - 981.12 \times 10^6 \times \frac{4}{100}$$

= 941.8752×10^6 kWh

Annual interest = 0.05 x 350 x 10^7

= **Rs: 17.5 ×10^7**

Annual depreciation = 0.06 x 350x 10^7

= **Rs. 21 x 10^7**

Fixed cost = Annual interest + Annual depreciation

= **17.5 x 10^7 + 21 x 10^7**

= **Rs. 38.5 x 10^7**

Total annual cost = Fixed cost + Running cost

= **38.5 x 10^7+ 55 x 10^7**

= **Rs. 93.5 x 10^7**

Cost of power generation

$$= \frac{Total\ annual\ cost}{Net\ energy} = \frac{93.5 \times 10^7}{941.8725 \times 10^6}$$

= **Rs. 0.9927**

= **99.27 paisa**

6) A power station supplies the following loads to the customers

Time in hrs	0 – 6	6 – 12	12 – 14	14 – 18	18 – 24
Load in MW	45	120	90	140	70

(a) Draw the load curve and load duration curve.

(b) Calculate the load factor.

(c)Calculate the plant capacity factor and utilization factor of the plant serving this load if its rated capacity is 170 MW

Solution:

(a) The load curve and load duration curve are drawn as shown in Figures

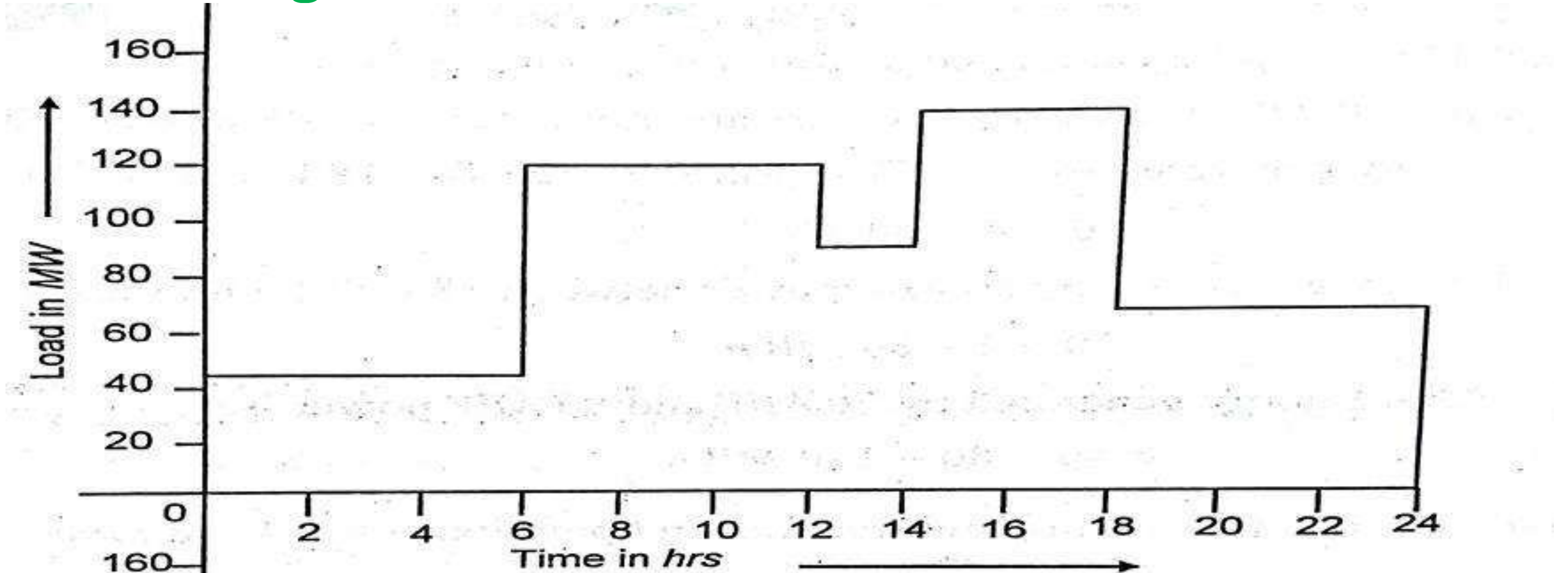
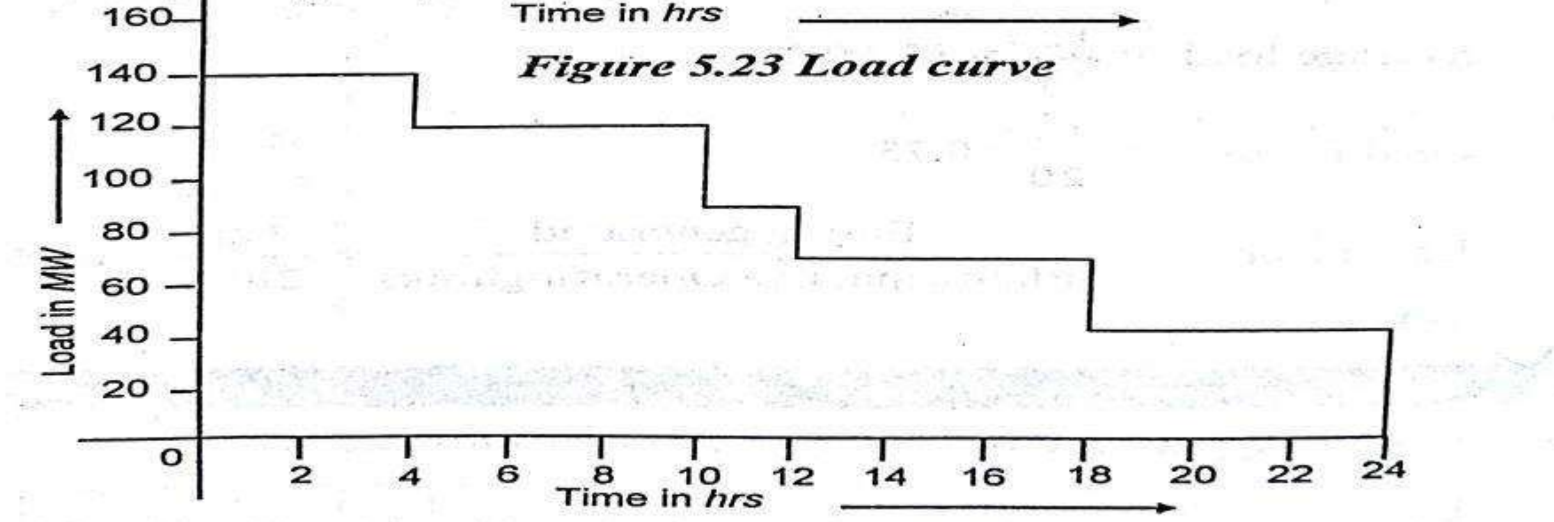


Figure 5.23 Load curve



b) Energy generated Area under load curve

$$= 45 \times 6 + 120 \times 6 + 90 \times 2 + 140 \times 4 + 70 \times 6$$

$$= 2150 \text{ MWh}$$

$$\text{Average Load} = \frac{2150}{24}$$

$$= 89.583 \text{ MW}$$

Maximum demand = 140 MW

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$= \frac{89.583}{140}$$

$$= 0.64$$

c) Plant capacity factor =

$$\frac{Energy\ generated}{Capacity\ of\ the\ plant\ x\ Operating\ in\ hrs}$$

$$= \frac{2150}{170\ x\ 24}$$

$$= \mathbf{0.52}$$

Utilization factor $= \frac{Maximum\ Load}{Capacity\ of\ the\ plant}$

$$= \frac{140}{170}$$

$$= \mathbf{0.823}$$

7) The loads on a power plant with respect to 24 hours are listed below.

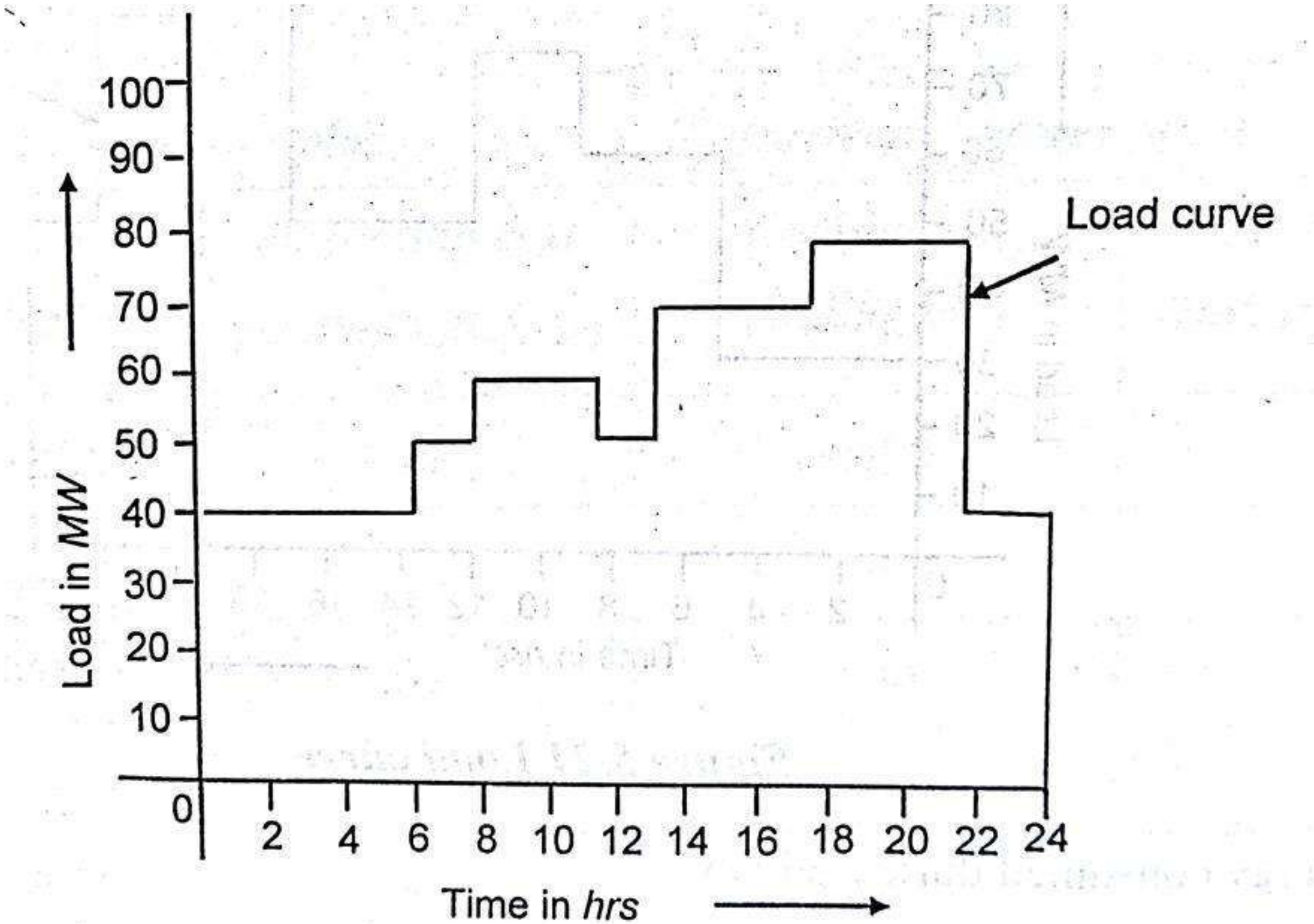
Time in hrs	0 – 6	6 – 8	8 – 12	12 – 14	14 – 18	18 –22	22-24
Load in MW	40	50	60	50	70	80	40

(a)Draw the load curve and find out the load factor of the power station.

(b)If the loads above 60 MW are taken by a standby unit of 20 MW capacity, find the load factor and use factor of the standby unit

Solution:

(a) Based on the data given, the load curve is drawn as shown in Figure



Energy generated area under the load curve

$$= 40 \times 6 + 50 \times 2 + 60 \times 4 + 50 \times 2 + 70 \times 4 + 80 \times 4 + 40 \times 2$$

$$= 1360 \text{MWh}$$

$$\text{Average load} = \frac{1360}{24}$$

$$= 56.667 \text{MW}$$

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$= \frac{56.667}{80}$$

$$= 0.708$$

(b) If the load above 60 MW is supplied by a standby unit of 20MW capacity, the energy generated by it can be calculated as follows:

Only 70 MW and 80 MW powers are more than 60 MW power. Therefore,

Energy generated by 70 MW power between 14 - 18 hours i.e. 4 hours is

= 10 x4 = 40 MWh

Energy generated by 80 MW power between 18 -22 hours

i.e. 4 hours is

= 20 x 4 = 80 MWh

Total Energy generated by 70 MW and 80 MW power is

= 40+ 80 = 120 MWh

Time during which the standby unit remains in operation

= 4 + 4 = 8hours

Average load $= \dfrac{120}{8}$

$= \mathbf{15\ MW}$

Load factor $= \dfrac{15}{20}$

$= \mathbf{0.75}$

Use factor $= \dfrac{Energy\ generated}{Plant\ capacity\ x\ Operating\ hrs}$

$= \dfrac{120}{20\ x\ 8}$

$= \mathbf{0.75}$

8) A central power station has annual factors as follows, Load factor = 60%; Capacity factor= 40%; Use factor = 45%; Power station has a maximum demand of 15,000 MW. Determine the annual energy production, reserve capacity over and above peak load and hours per not in service.

Solution:

a) Annual energy production

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$0.6 = \frac{\text{Average Load}}{15{,}000}$$

Average Load = 9000 kW

Annual energy production = 9000 x 24 x 365

= 78840000 kW-hr

b) Reserve capacity over and above the peak Load

$$\text{Capacity Factor} = \frac{\text{Average Load}}{\text{Plant Capacity}}$$

$$\text{Plant Capacity} = \frac{9000}{0.4}$$

$$= 22{,}500 \text{ kW}$$

Reserve capacity over of above the peak load

$$= 22{,}000 - 15{,}000$$

$$= 7500 \text{ kW}$$

c) Hour per year not in use (or) service

$$\text{Use Factor} = \frac{\text{Annual energy production in given time period}}{\text{Maximum energy production by the plant}}$$

$$0.45 = \frac{78840000}{22{,}500 \times \text{Hours in operation}}$$

Hours in operation = 7786.67 hrs

Hours not in use in a year = (24 x 365) – 7786.67

= 973.33 hrs

POWER PLANT ENGINEERING

ABOUT CHAPTERS

- Coal Based Thermal Power Plants
- Diesel, Gas Turbine & Combined Cycle Power plants
- Nuclear Power plants
- Power From Renewable Energy
- Energy, Economics &Environmental Issues of power plants

World top 20 largest power plants

Rank	Station	Country	Capacity (MW)	Annual generation (TWh)	Type
1.	Three Gorges Dam	China	22,500	93.5 (2016)	Hydro
2.	Itaipu Dam	Brazil Paraguay	14,000	103.09 (2016)	Hydro
3.	Xiluodu	China	13,860	55.2 (2015)	Hydro
4.	Guri	Venezuela	10,235	47 (average)	Hydro
5.	Tucuruí	Brazil	8,370	21.4 (1999)	Hydro

6.	Kashiwazaki-Kariwa	Japan	7,965	60.3	Nuclear
7.	Grand Coulee	United States	6,809	21	Hydro
8.	Xiangjiaba	China	6,448	30.7	Hydro
9.	Longtan	China	6,426	17.3	Hydro
10.	Sayano-Shushenskaya	Russia	6,400	24.9	Hydro

11.	Bruce	Canada	6,238	47.63	Nuclear
12.	Krasnoyarsk	Russia	6,000	23.0	Hydro
13.	Hanul	South Korea	5,881	48.16	Nuclear
14.	Hanbit	South Korea	5,875	47.62	Nuclear
15.	Nuozhadu Dam	China	5,850	23.9	Hydro

16.	**Zaporizhia**	**Ukraine**	**5,700**	**48.16**	**Nuclear**
17.	**Robert-Bourassa**	**Canada**	**5,616**	**26.5**	**Hydro**
18.	**Shoaiba**	**Saudi Arabia**	**5,600**		**Fuel oil**
19.	**Surgut-2**	**Russia**	**5,597**	**39.85**	**Natural gas**
20.	**Taichung**	**Taiwan**	**5,500**	**42**	**Coal**

UNIT - I

COAL BASED THERMAL POWER PLANTS

LAYOUT OF STEAM POWER PLANT

- **Main circuits,**

  1. **Coal and Ash circuit**
  2. **Water and steam circuit**
  3. **Air and Flue gas circuit**
  4. **Cooling water circuit**

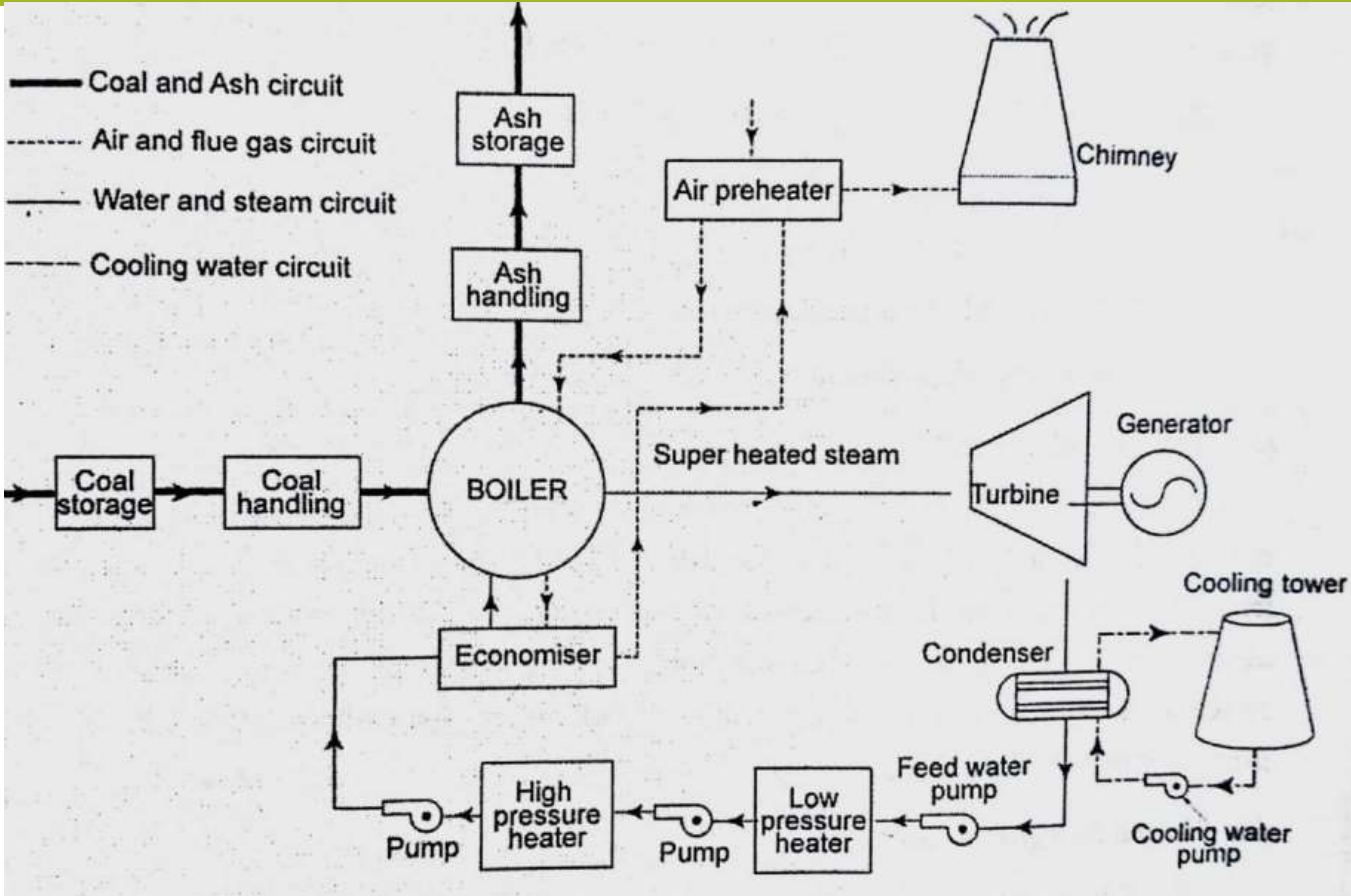


Figure 1.1 Layout of steam or thermal power plant

Advantages

- The unit capacity of a thermal power plant is more.
- Life of the plant is more (25-30 years) as compared to diesel plant (2-5 years).
- Repair and maintenance cost are low when compared with diesel plant.
- Initial cost of the plant is less than nuclear plants.

- **No harmful radioactive wastes are produced as in the case of nuclear plant.**
- **Unskilled operators can operate the plant.**
- **The power generation does not depend on water storage.**

Disadvantages

- Thermal plants are less efficient than diesel plants
- Starting up the plant and bringing into service takes more time.
- Cooling water required is more.
- Space required is more
- Storage required for the fuel is more
- Ash handling is a big problem.
- Not economical in areas which are remote from coal fields

High Pressure Boiler

- The pressure range is greater than 25 bar
- The temperature is around 500 C
- Production of steam rate is more than 250 $\frac{tons}{hr}$

Advantages

i) **Scale formation is eliminated due to high velocity of water through tubes**

ii) **Light weight tubes with better heating surface arrangement can be used**

iii) **The space required is less**

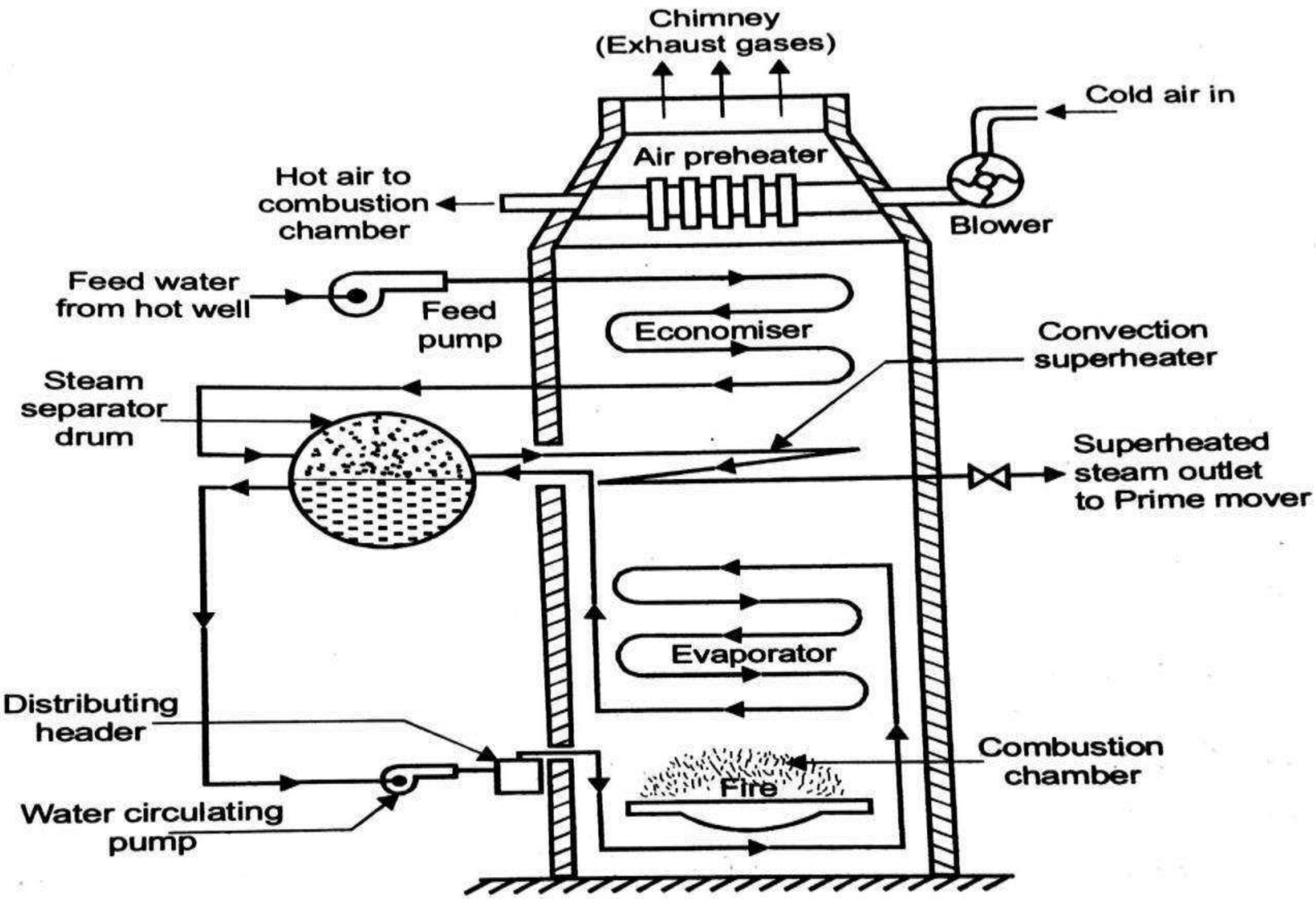
iv) **All parts are uniformly heated. So over heating is reduced**

v) **Efficiency of power plant is increased up to 40% to 45%**

Types of High pressure boiler,

- **Lamont Boiler**
- **Benson Boiler**
- **Velox Boiler**
- **Loffler Boiler**

LAMONT BOILER



BENSON BOILER

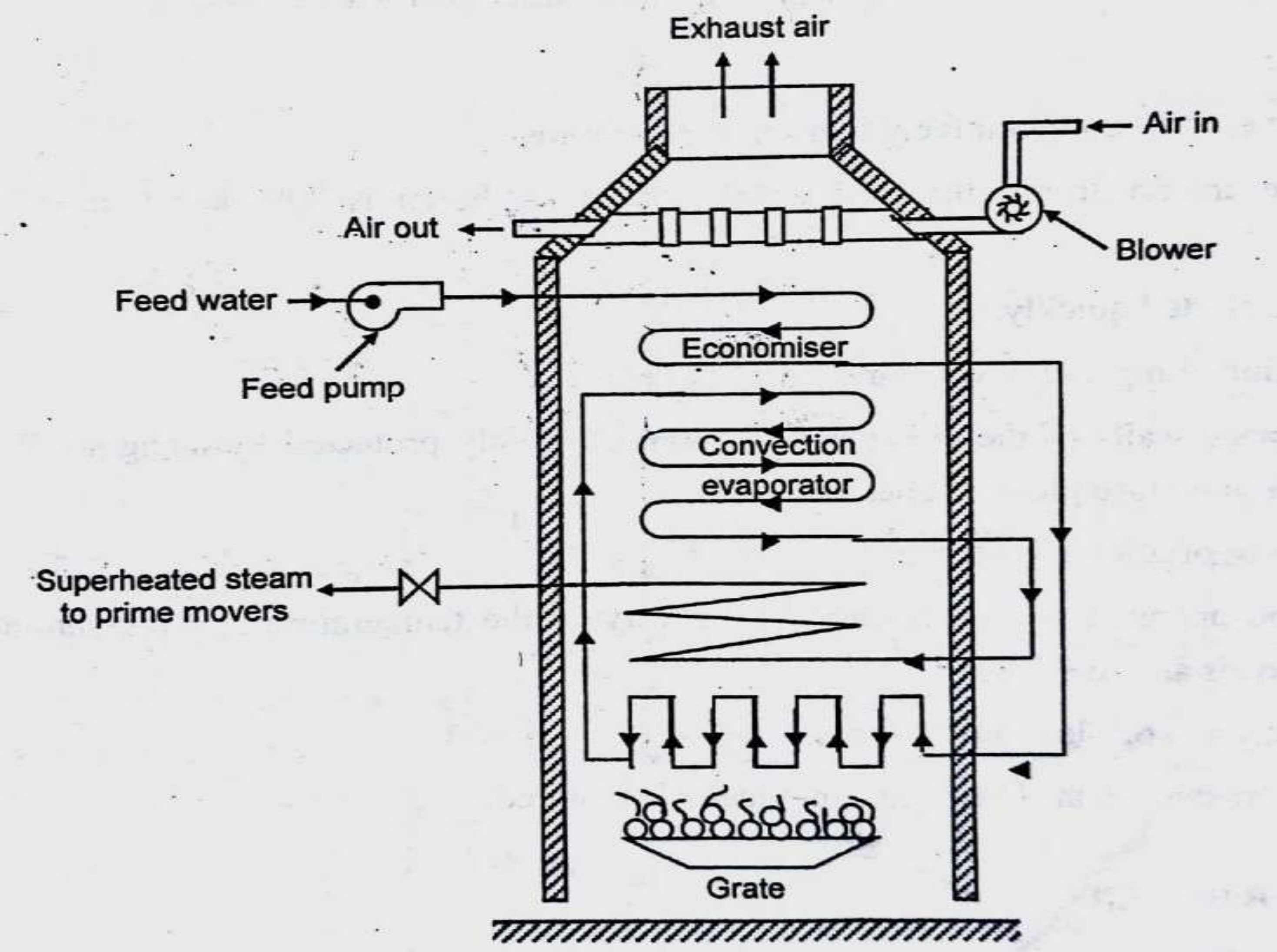
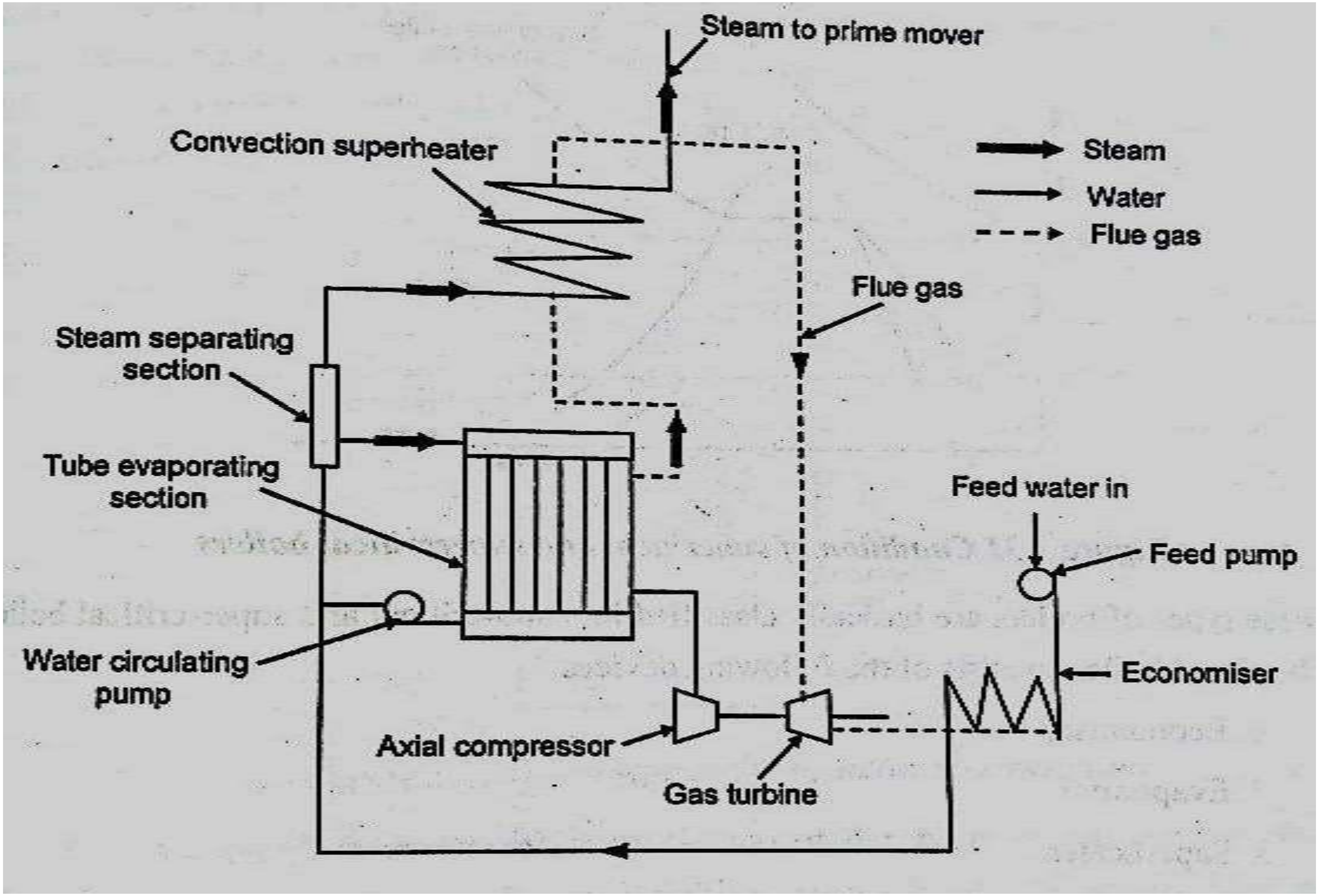
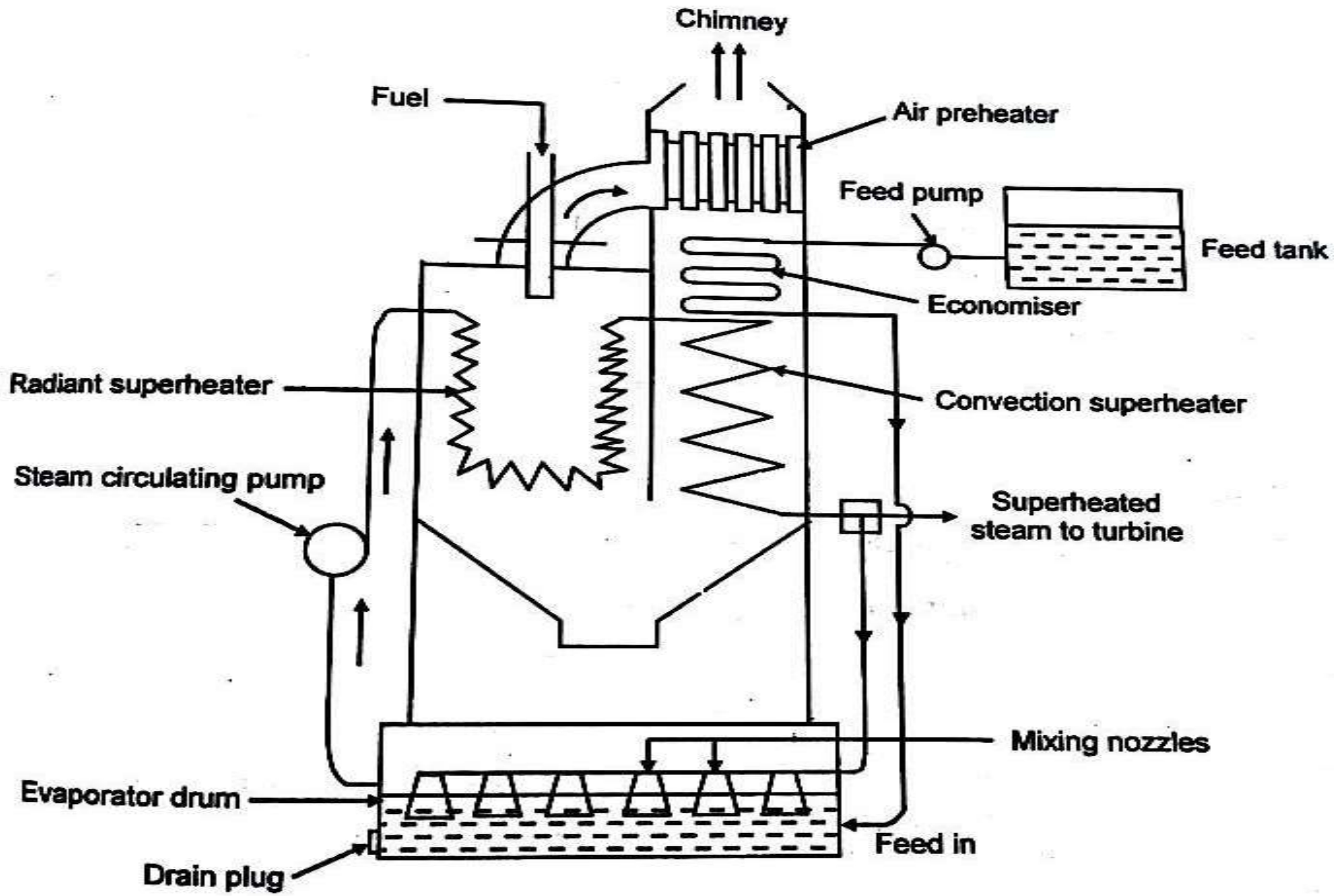


Figure 1.28 Benson Boiler

VELOX BOLIER



LOFFLER BOILER



Supercritical Boiler

- **The power plant which is operated above the critical pressure and temperature condition is called super critical boiler.**
- **Mainly, Super critical boilers are water tube boiler.**
- **The pressure range of 125 Atmospheric to 300 atmospheric & The temperature range of 510 C to 660C.**

Types of super critical Boiler,

1) Drum type boiler

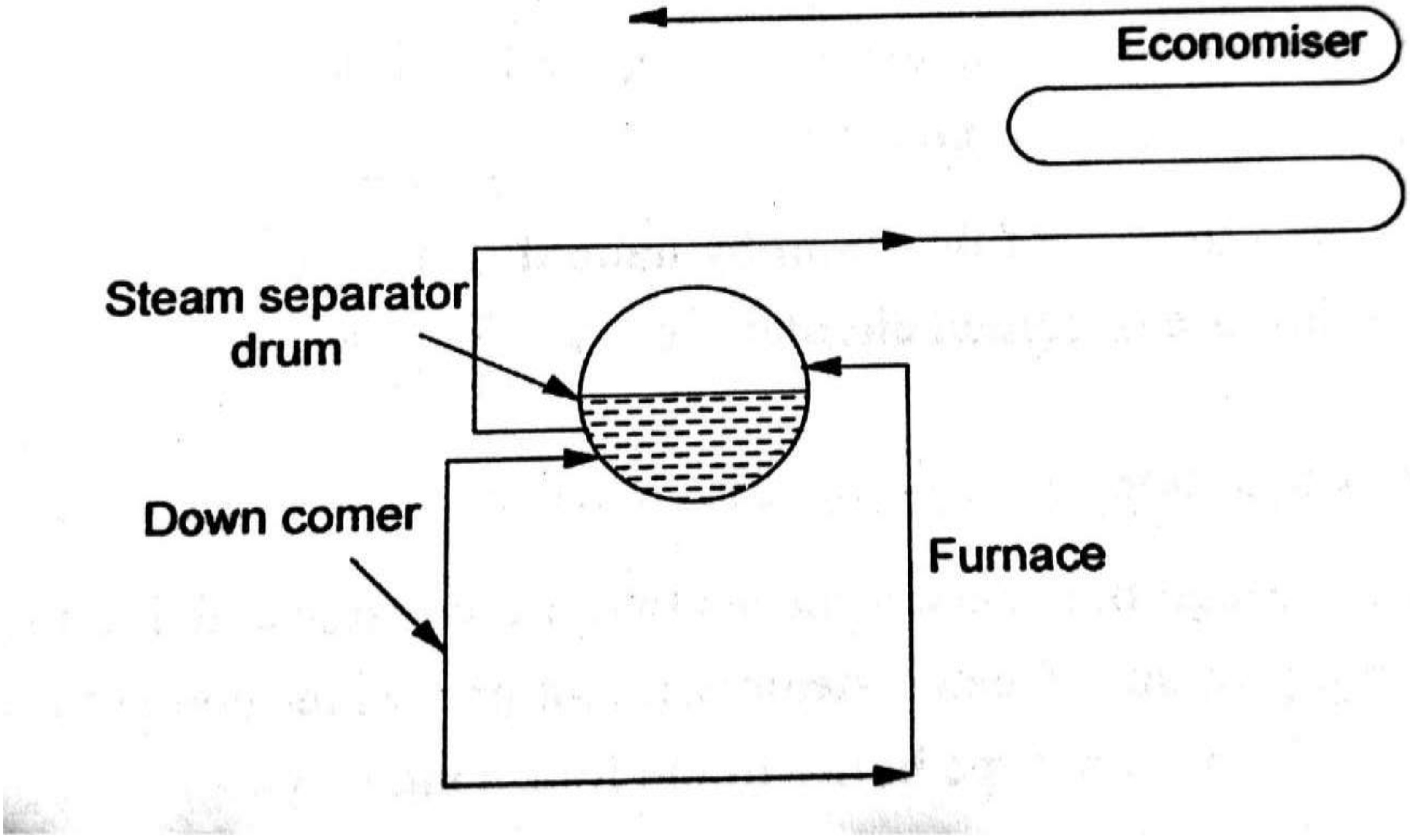
   a) Natural circulation

   b) Forced circulation

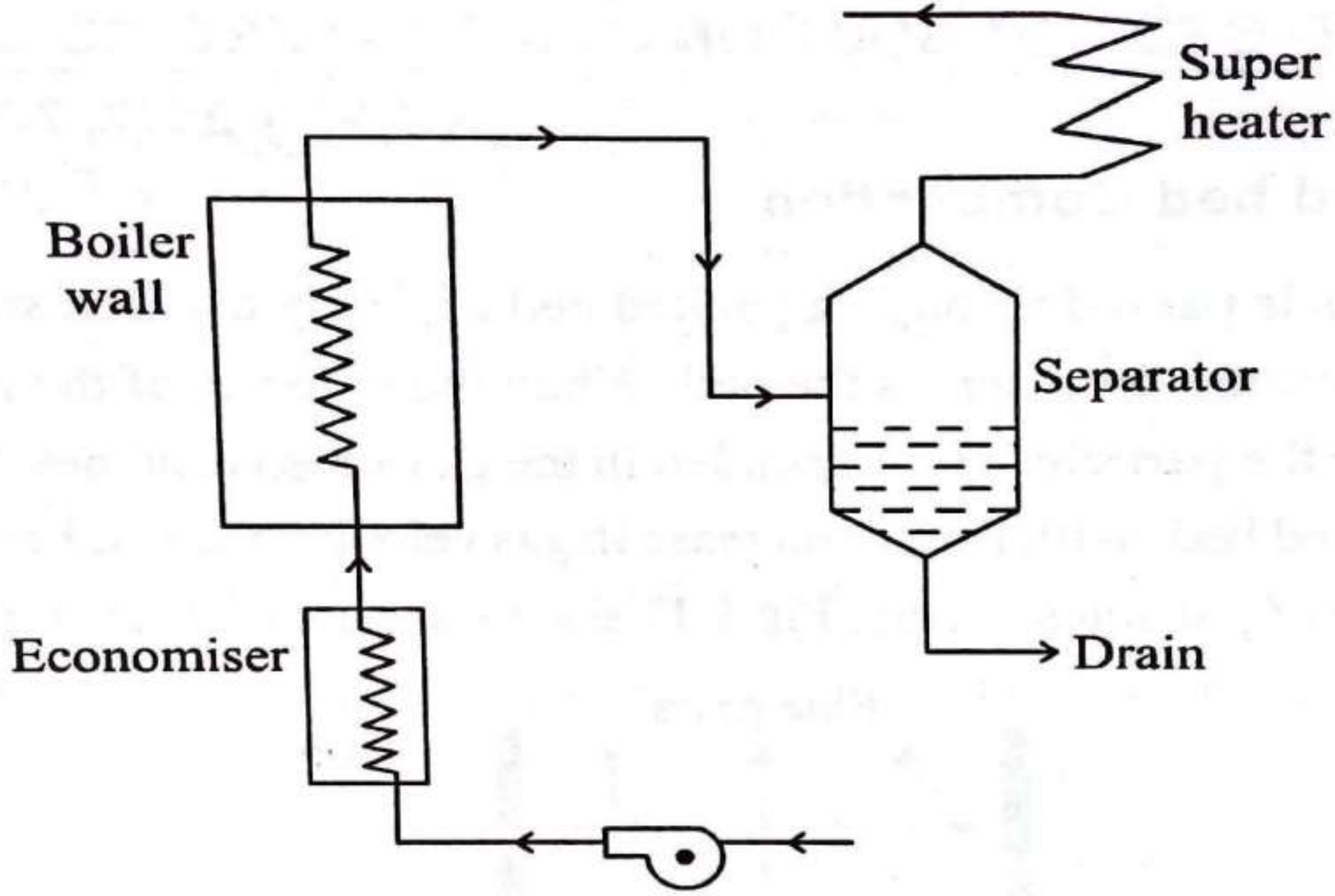
2) Once – through boiler

Drum type boiler

a) Natural circulation



Once – Through boiler



Merits:

1. **It produces high thermal efficiency**
2. **Heat transfer rate is high.**
3. **The erosion and corrosion are minimized**
4. **It is easy to operate**
5. **More stable pressure level**

Boiler Mounting,

- **The devices which are used for safety features and effective functioning.**

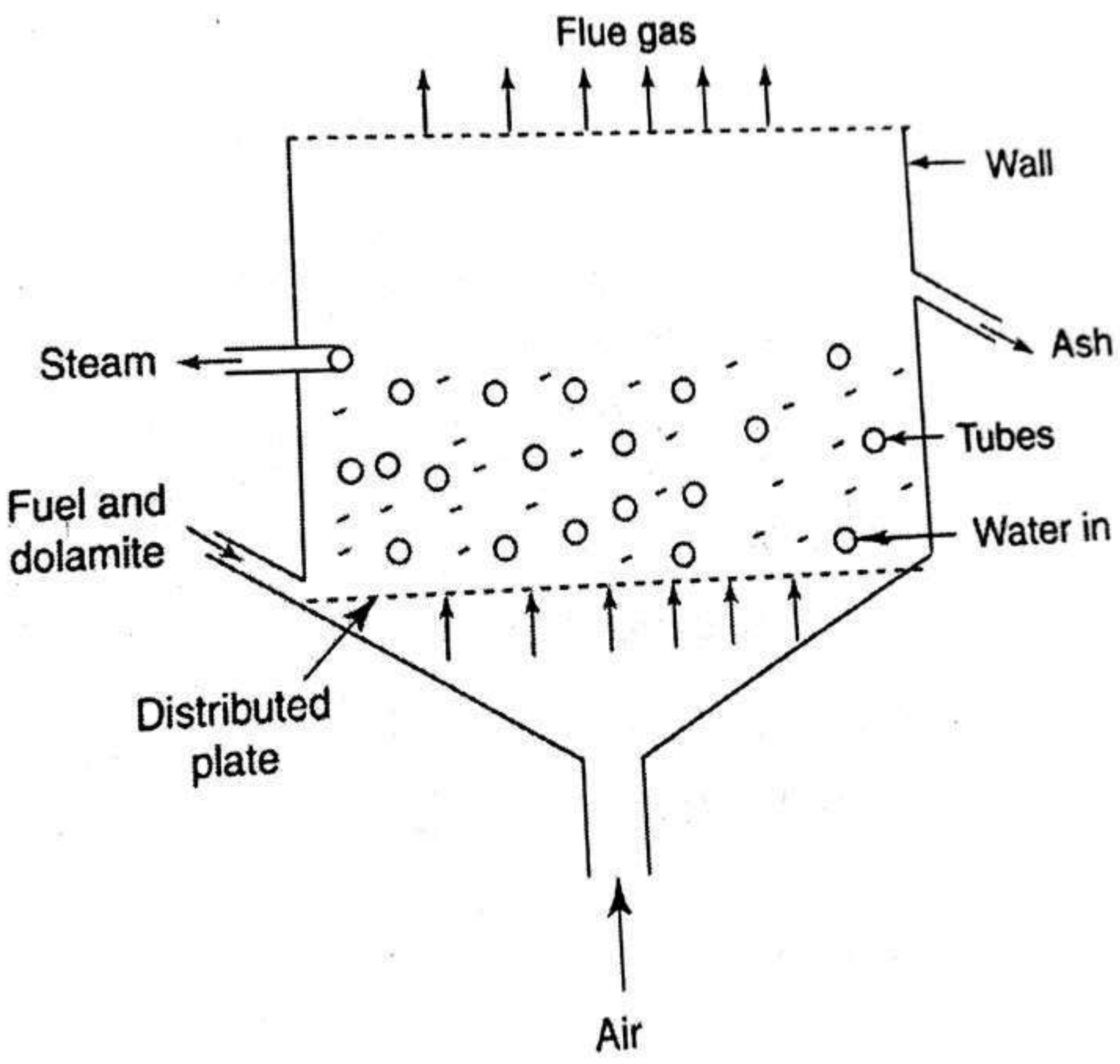
1) **Pressure gauge**
2) **Water level indicator**
3) **Safety valve**
4) **Fusible plug**
5) **Blow-off cock**
6) **Feed check valve**
7) **Man holes**

Boiler Accessories,

- **The devices which are used to increase the efficiency of the boiler.**

1) Economizer
2) Air-preheater
3) Super heater
4) Steam trap
5) Deaerators

Fluidized Bed Combustion



Types of FBC Boiler

- **Boilers which are used to produce steam from fossil fuel and waste fuels by using the technique FBC are called Fluidized Bed Combustion boilers**
- **There are two types,**

  1) Bubbling Fluidized Bed Boilers(BFB)

  2) Circulating Fluidized Bed Boilers(CFB)

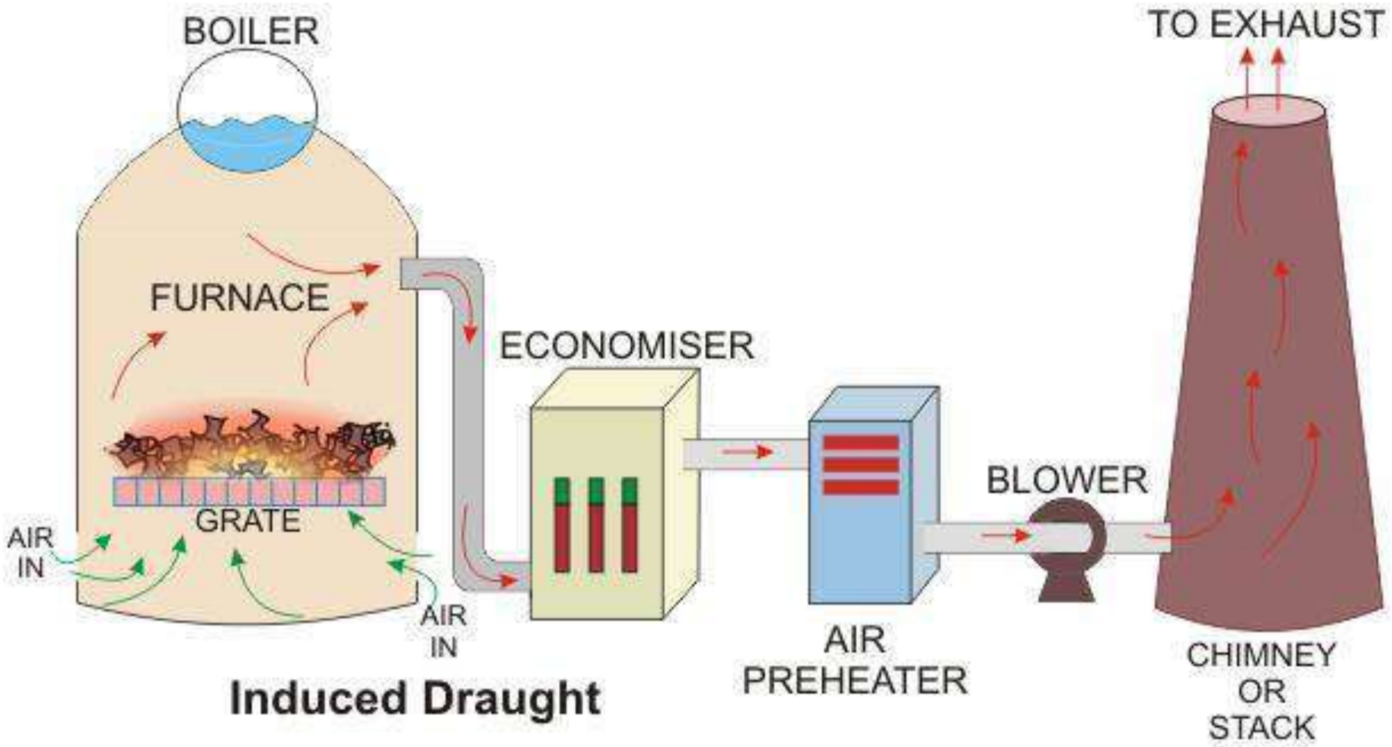
Draughts

- To supply the required quantity of air to the furnace.
- To remove the burnt products from the system.

Two types of Draughts

1. Natural Draught
2. Artificial Draught
   a) Forced Draught fan
   b) Induced Draught fan

Natural Draught



Natural Draught

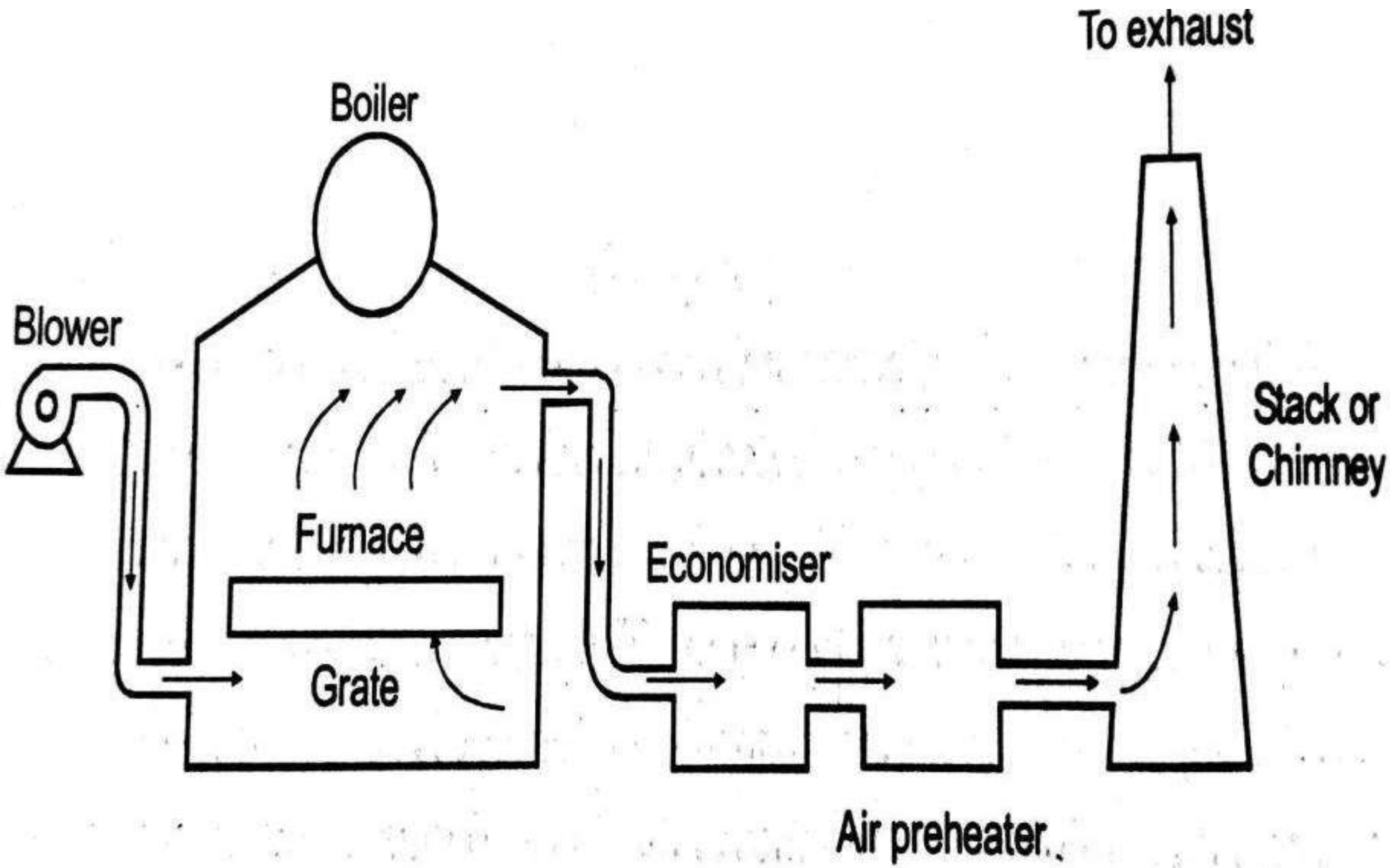
- **Advantages**

  1. **Flow of air is created by chimney itself.**
  2. **No fans are needed, So the power consumption is less**
  3. **It is a self-supported structure.**
  4. **Less ground area is required.**

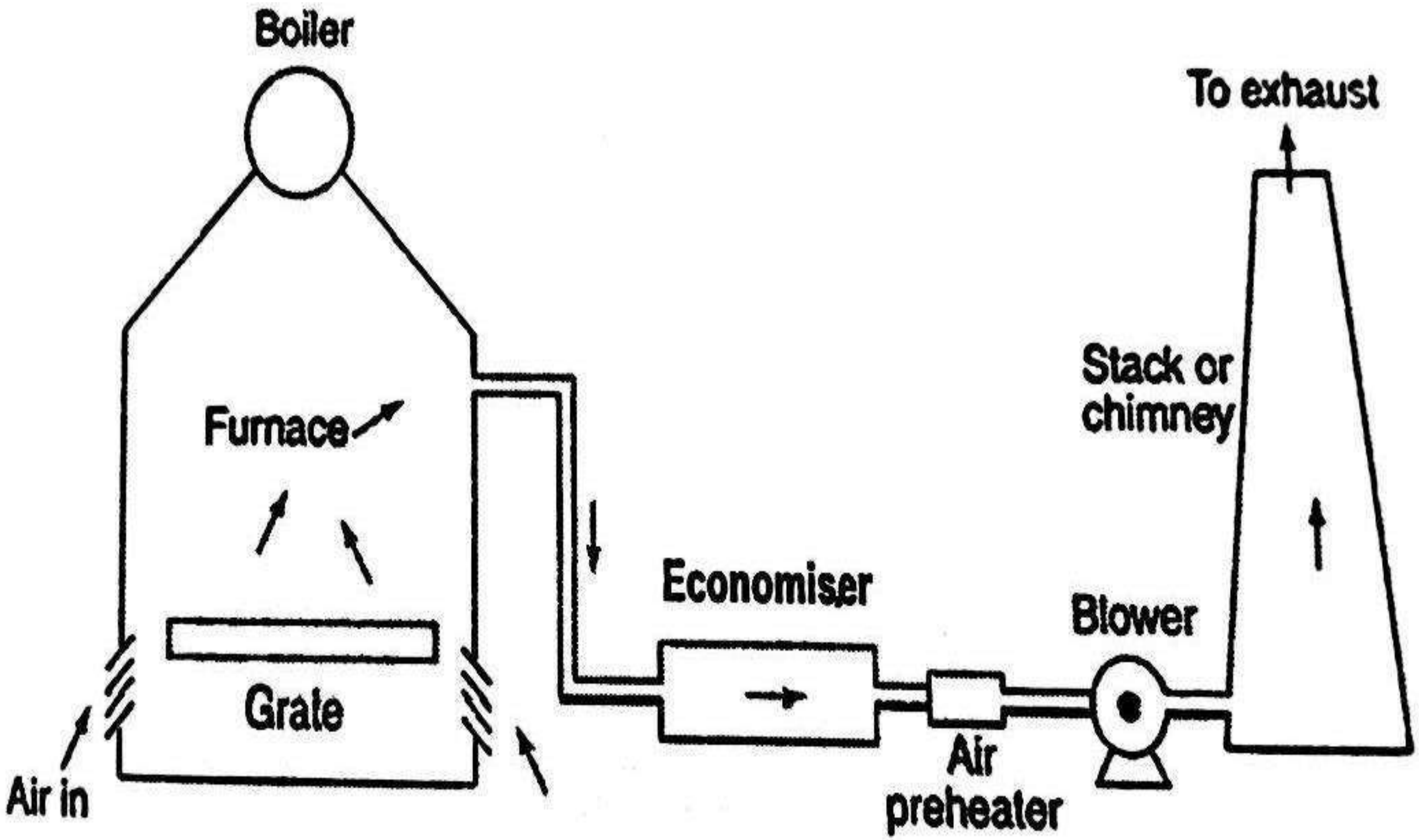
- **Disadvantages:**

  1. **Performance varies with seasonal change.**
  2. **Initial cost is high**

Forced draught fan



Induced draught fan



Condenser

- **Need of condenser:**

The condenser is a device which is used to convert steam into water.

Classification:

1. Based on contact

a) Surface condenser

b) Jet condenser

2. Based on type of cooling

a) Water cooled condenser

b) Air cooled condenser

3. Based on type of flow

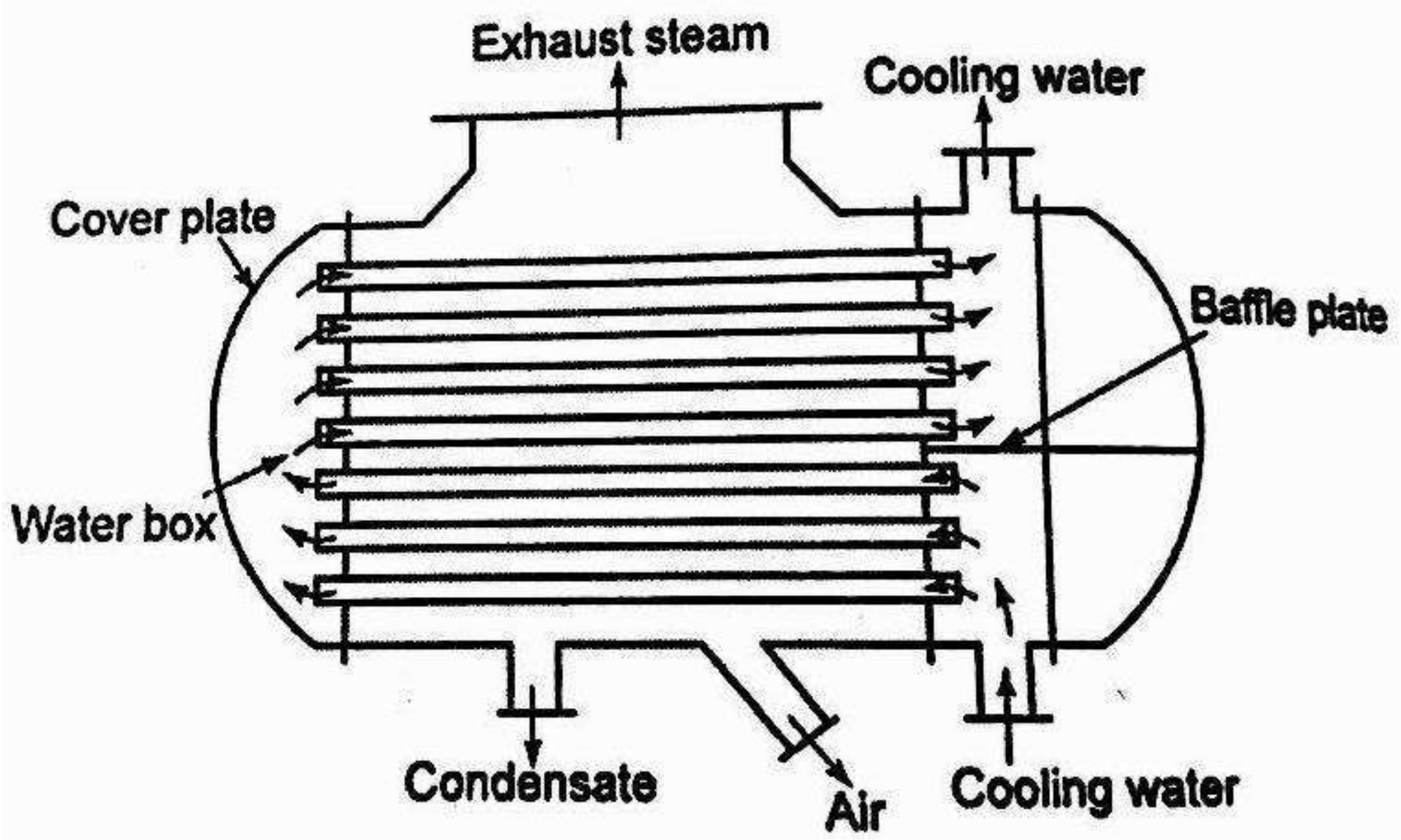
a) Down flow condenser

b) Central flow condenser

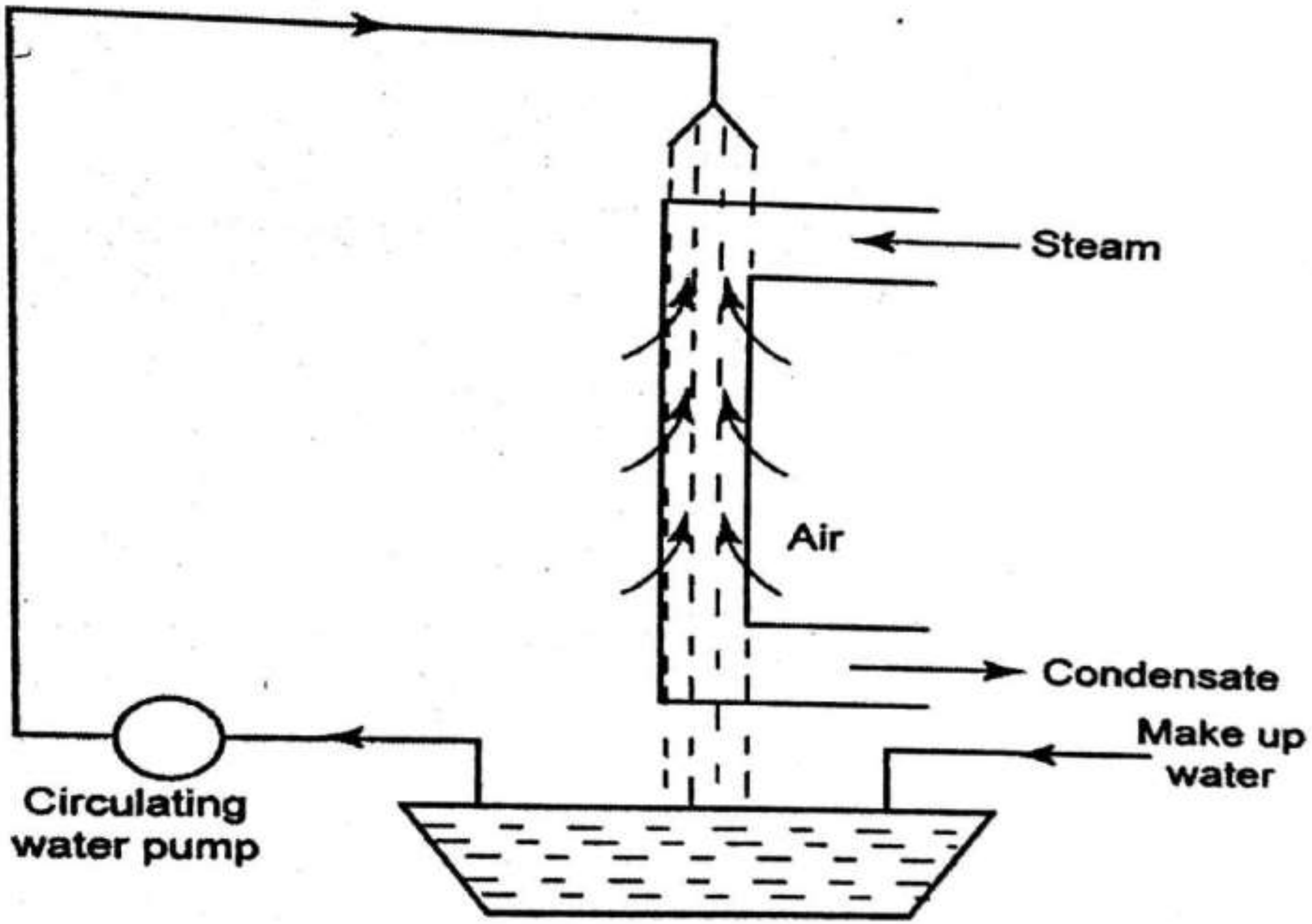
c) Evaporation condenser

Surface Condenser

1) Down flow condenser



2) Evaporation Condenser



Advantages of surface condenser

1. **High vacuum can be obtained in the surface condenser.**
2. **To increase the thermal efficiency of the plant.**
3. **The condensate can be used as boiler feed water.**
4. **Even poor quantity of cooling water can be used.**

Disadvantages of surface condenser

1. It is bulky and therefore, it requires more space.
2. The capital cost is more
3. Maintenance cost & Running cost are high.

Cooling Towers

Purpose of cooling Tower,

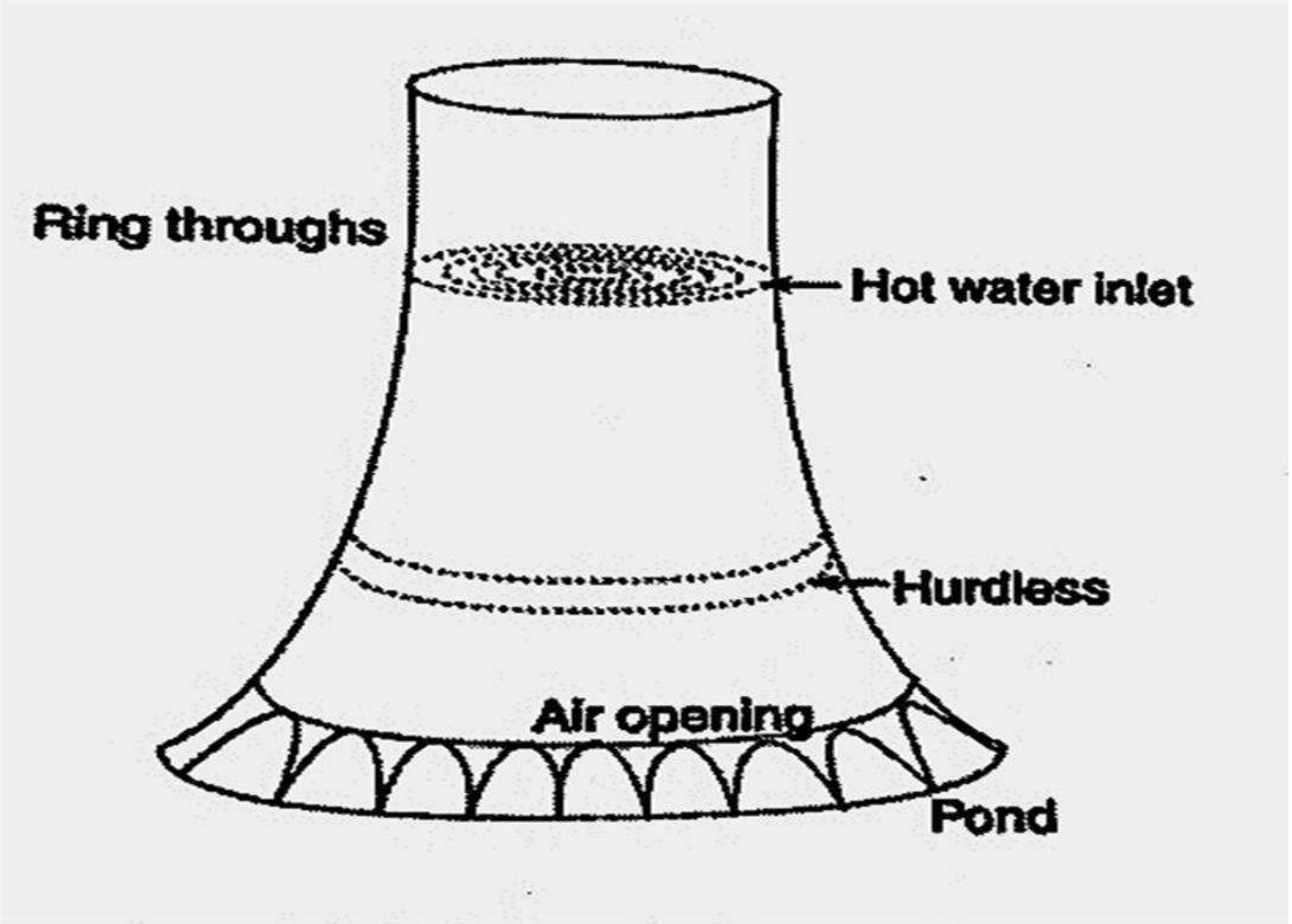
- It is used to control the temperature of water required for the plant.
- It is reduced the water consumption of the plant.

Types,

1) Wet type

2) Dry type

Hyperbolic Cooling Tower



Dust Collector

- **To avoid the atmosphere pollution the fly ash must be removed from the gaseous products before they leave the chimney.**

Types,

1) Mechanical Dust Collector

a) Gravitational separator

b) Cyclone separator

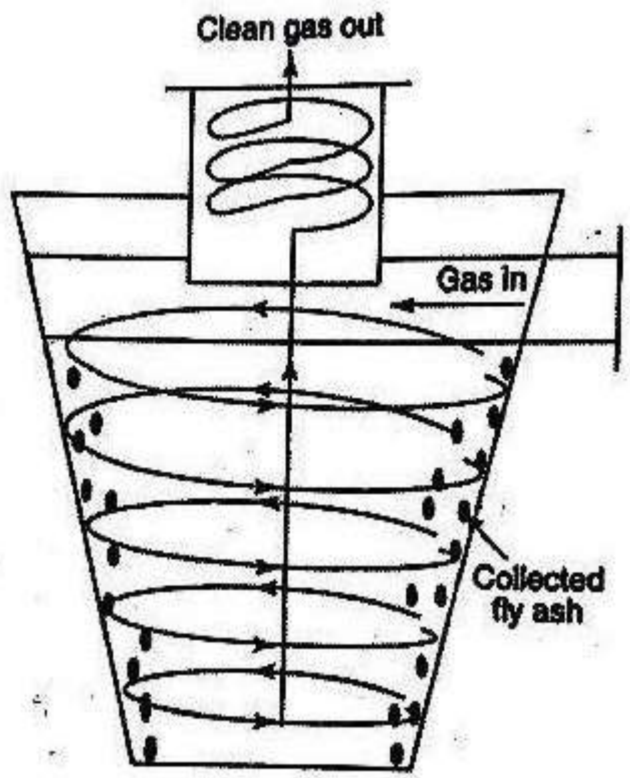
c) Scrubber

d) Electro static precipitator(ESP)

2) Electrical Dust Collector

Cyclone Separator

- **The overall efficiency of the Cyclone separator is depending on the dust particles size. Some of these values are given**



- **Advantages:**
  i) **Efficiency is higher when large size particles are collected**

  ii) **Maintenance cost is less.**

  iii) **Efficiency increases.**
- **Disadvantages:**
  i) **It requires more power than other collectors.**

  ii) **The pressure loss is high.**

Ash Handling System

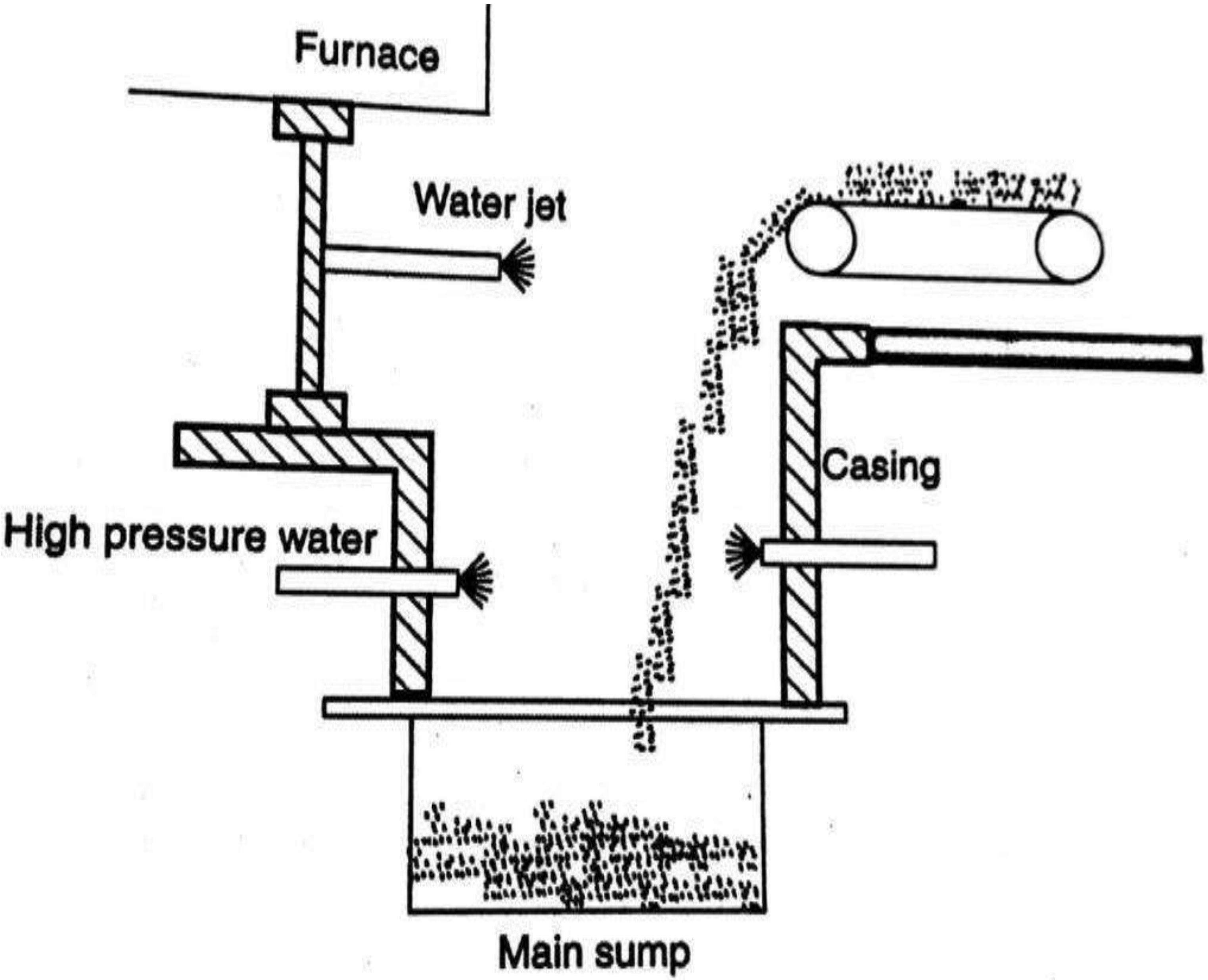
Ash Handling System

A) Hydraulic system:-

It can be divided into two group,

1) Low velocity system

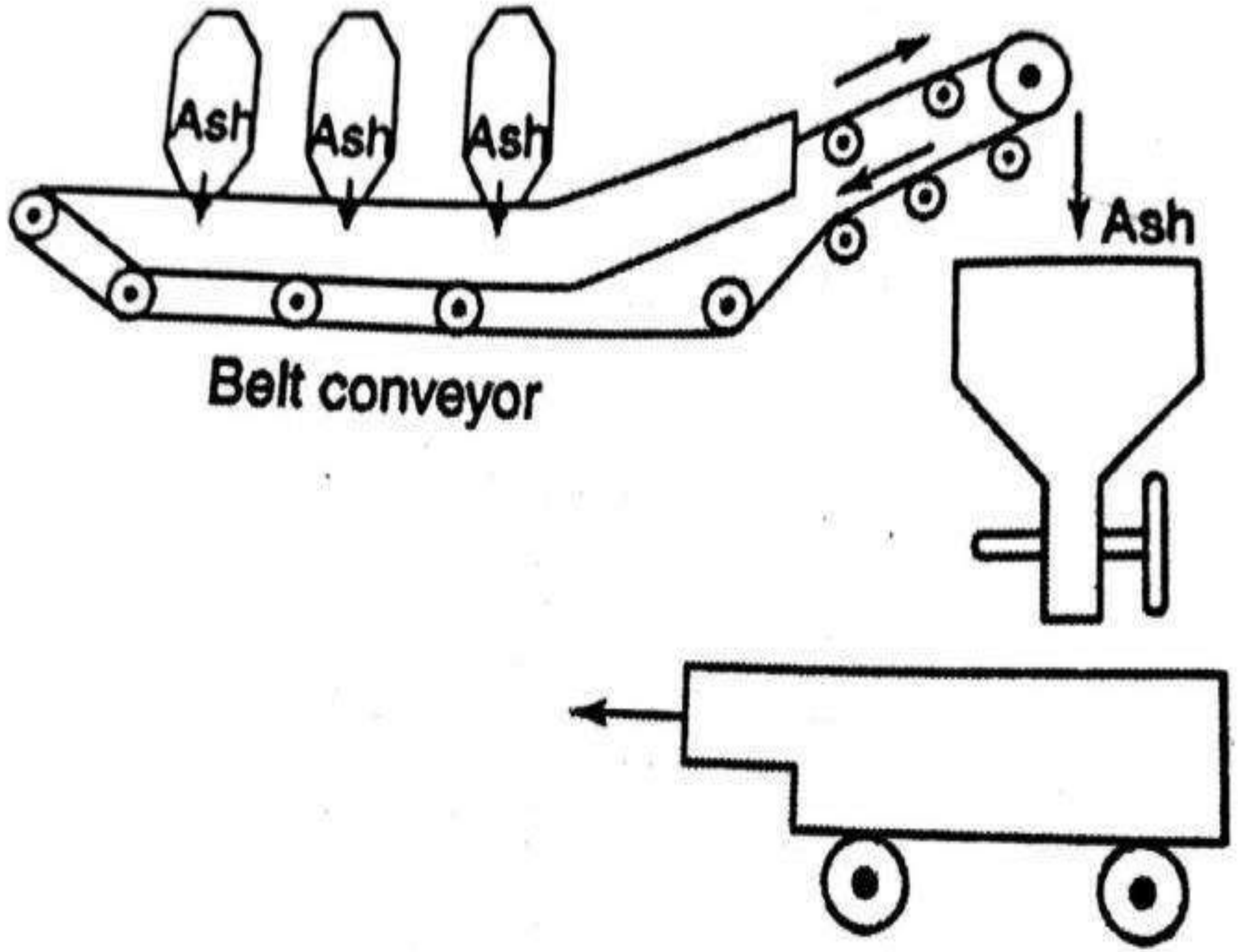
2) High velocity system



Furnace
Water jet
Casing
High pressure water
Main sump

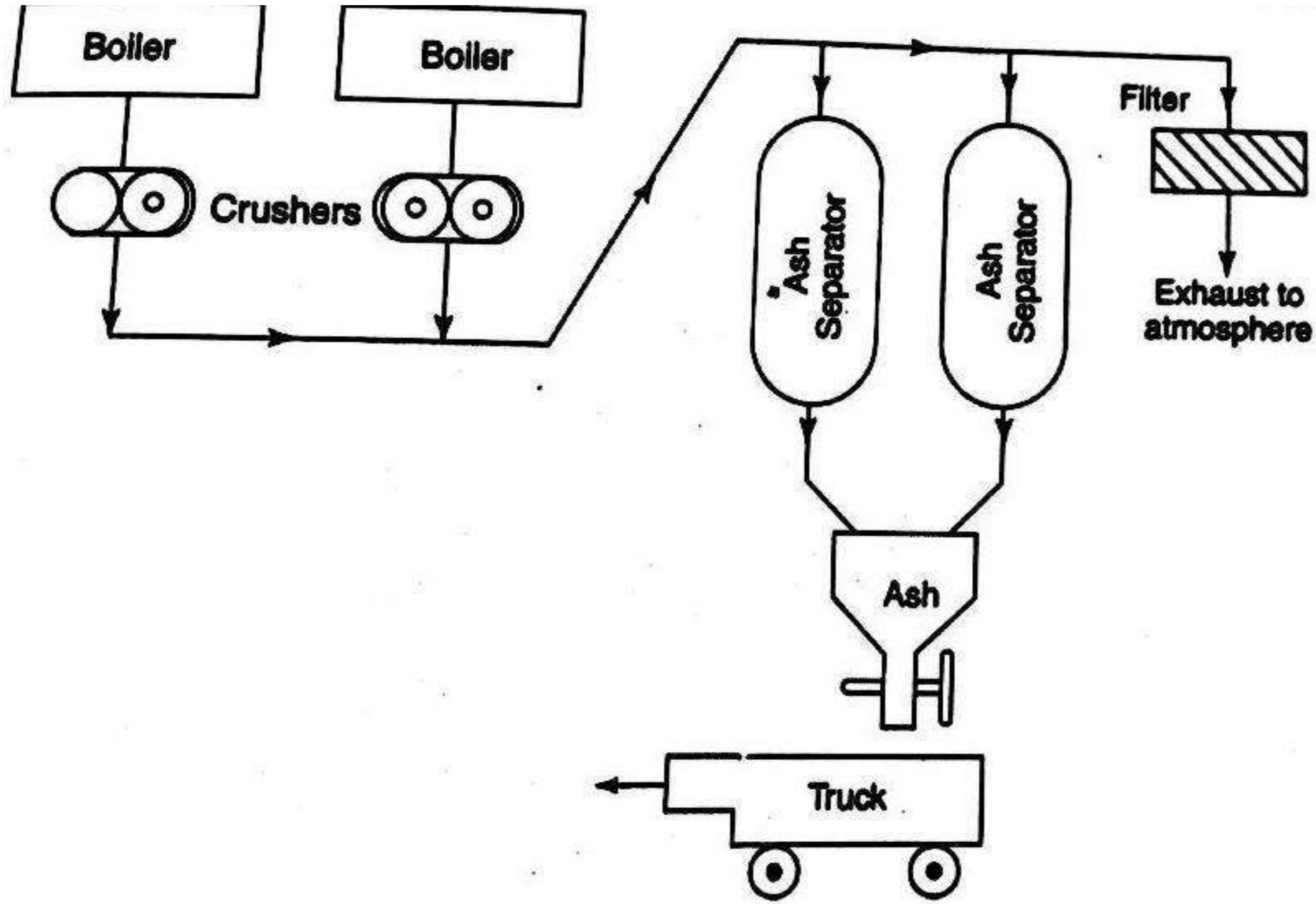
Advantages:

1. Ash carrying capacity is high.
2. The whole system is clean.
3. Total system is enclosed
4. Discharge of ash is at considerable distance
5. Working parts are not contact with ash



Ash
Ash
Ash
Ash
Belt conveyor

C) Vacuum extraction system:



Cogeneration

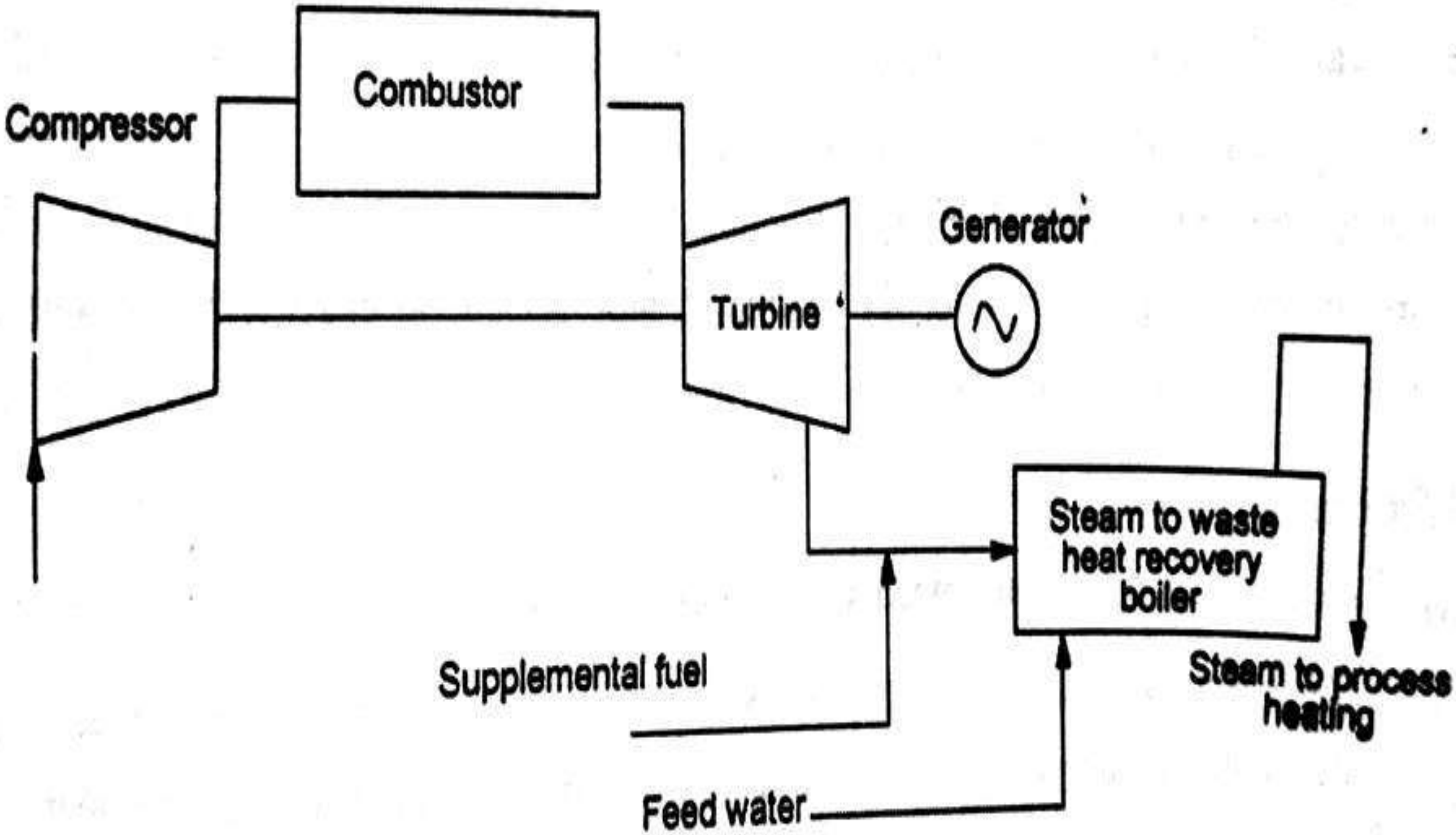
- **It is also called combined heat power(CHP)**
- **For producing different form of energy by using a single source of fuel.**
- **The fuel may be natural gas, oil, diesel, wood and coal**

Two types of cogeneration power plants,

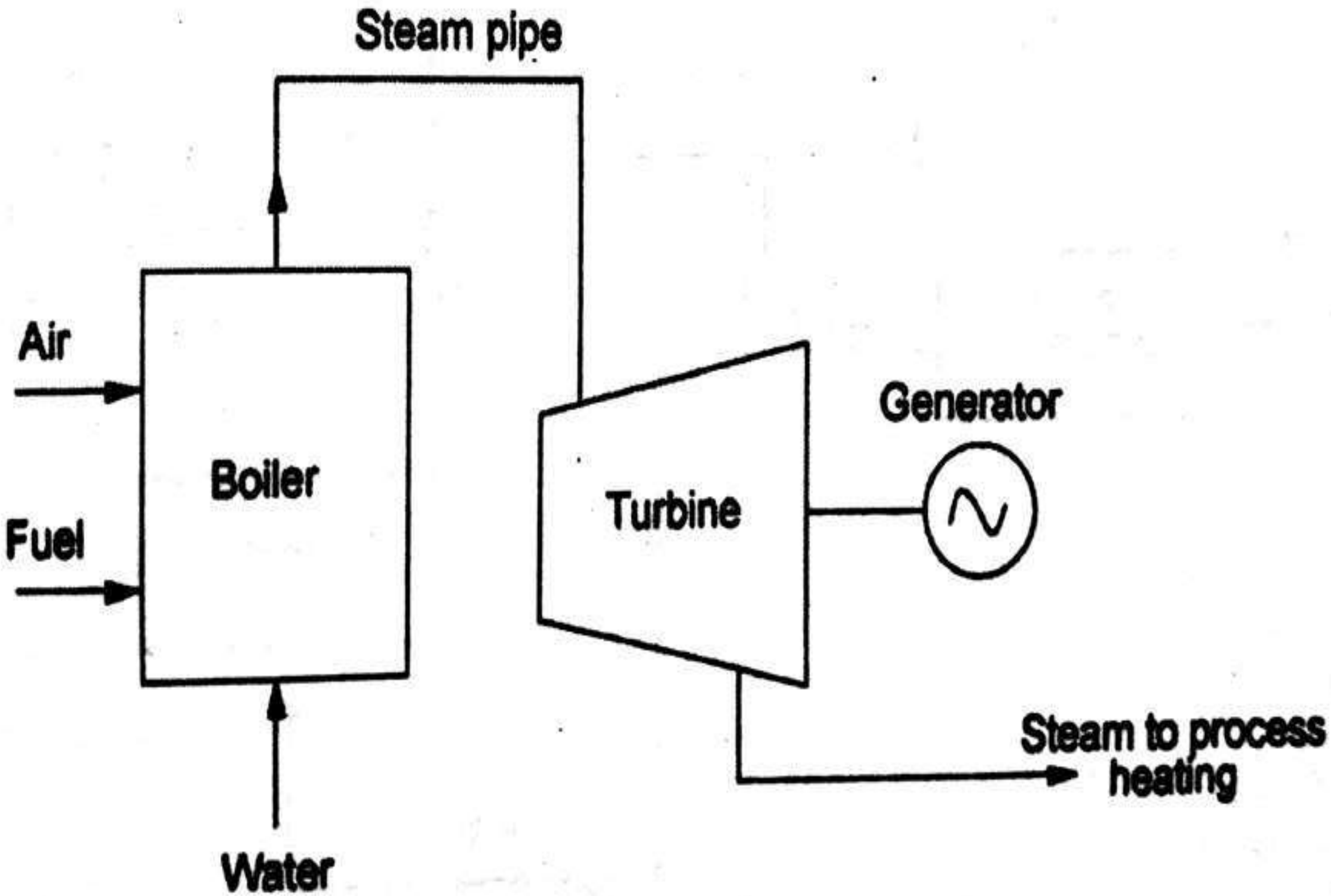
1) Topping cycle power plant

2) Bottoming cycle power plant.

Gas Turbine Topping CHP plant



Steam Turbine Topping CHP plant



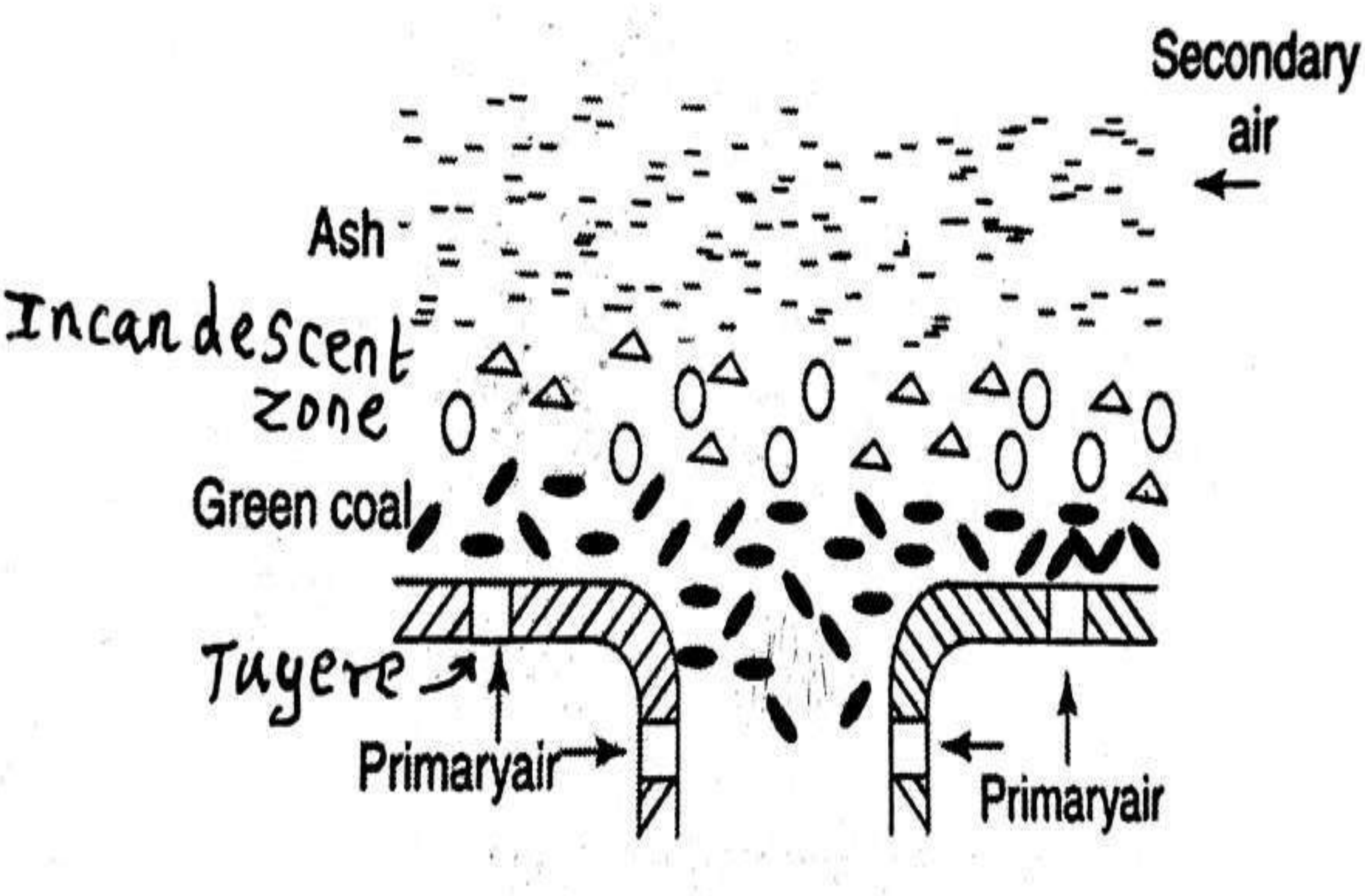
STOKERS

- **Stokers are used for feed solid fuels into the furnace in medium and large size power plants**
- **Classified into two types,**

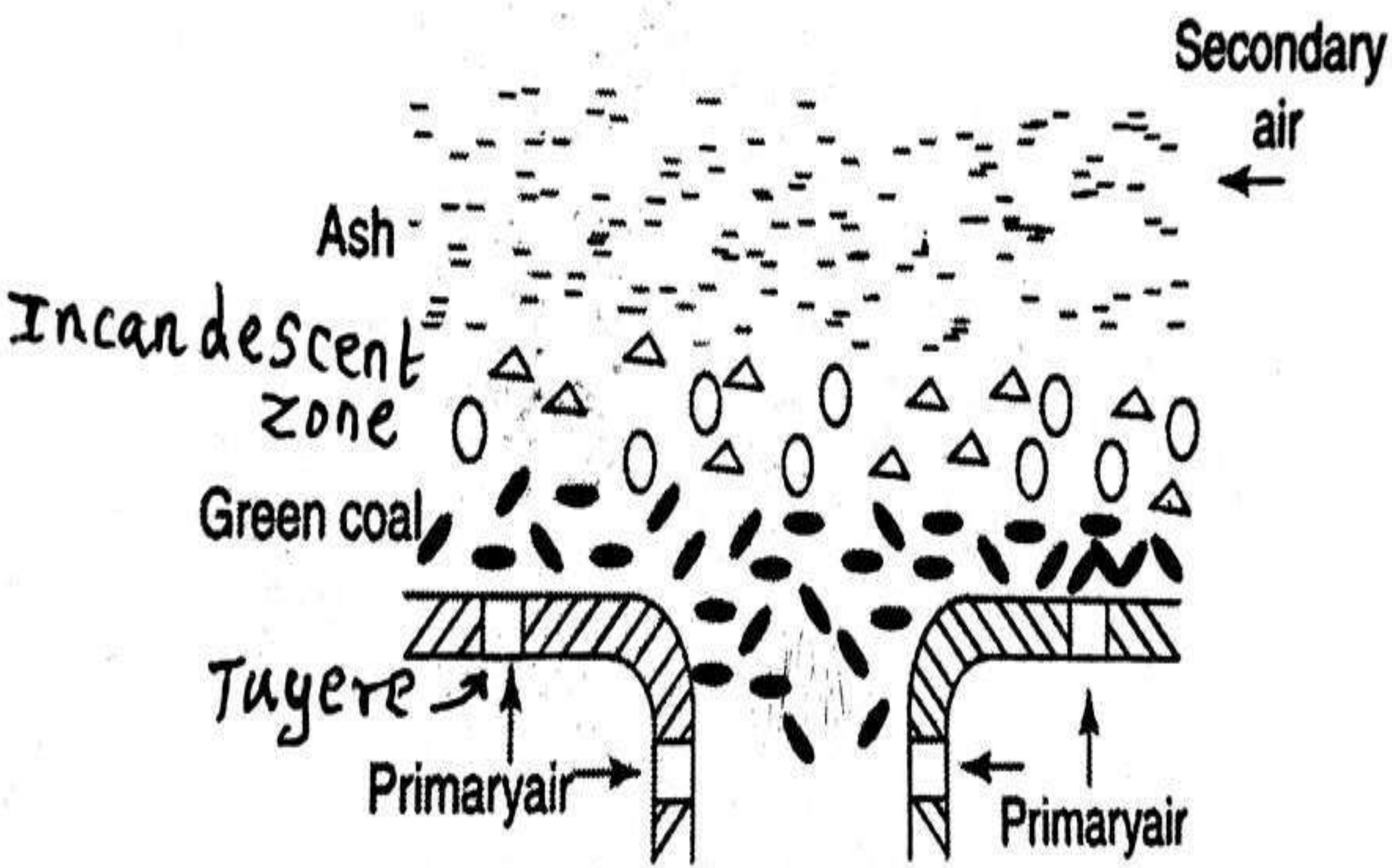
  1) Over feed stokers

  2) Under feed stokers

Over feed stokers



Under feed stokers



Advantages:

1) **Part load efficiency is high**
2) **It has high thermal efficiency**
3) **It has self-cleaning grates**
4) **Variety of coals can be used**
5) **It is more suitable for variable air conditions.**

Coal Handling System

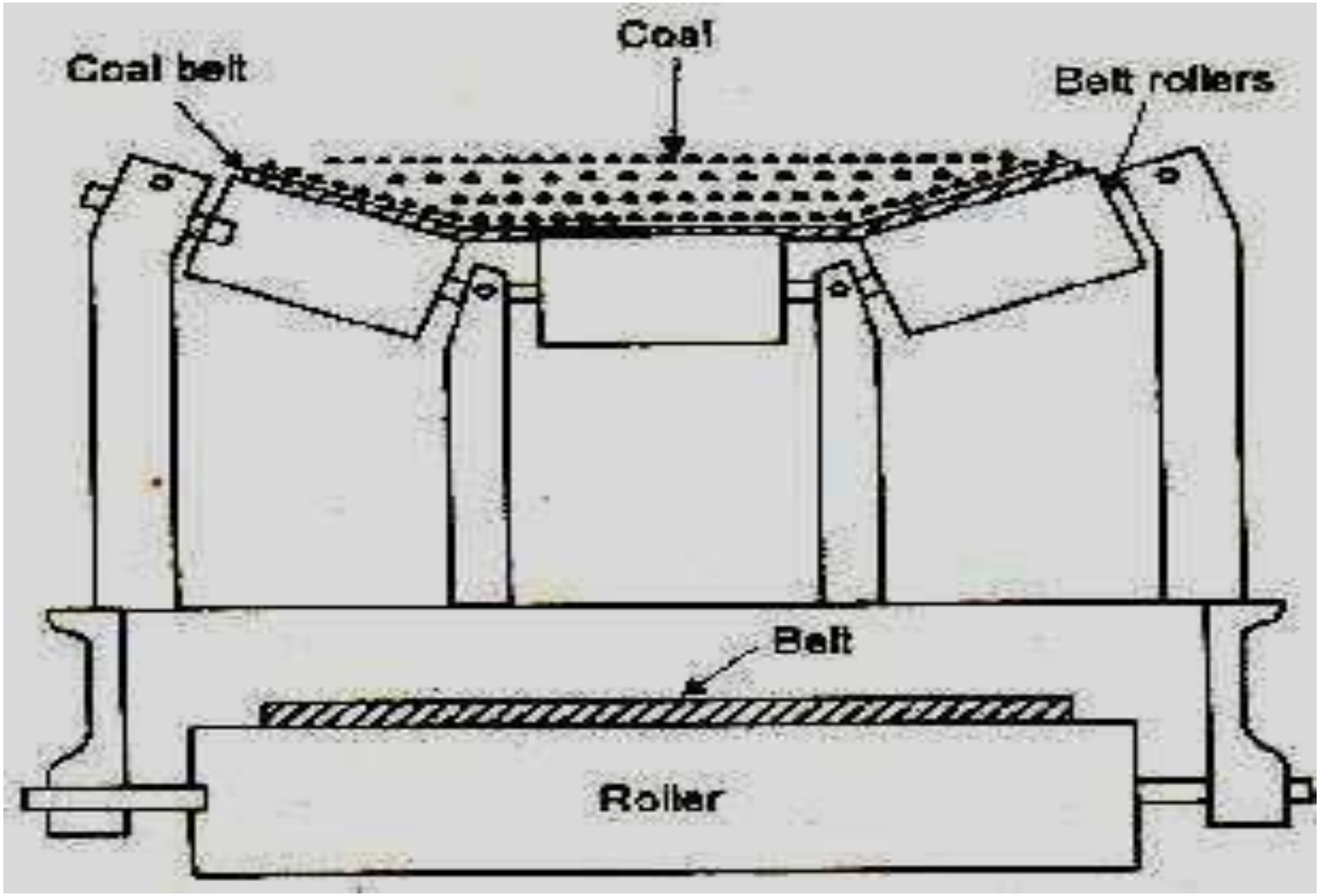
The various steps involved in coal handling are as follows:

- **Coal delivery.**
- **Unloading**
- **Preparation**
- **Transfer**
- **Outdoor storage**
- **Covered storage**
- **In-plant handling**
- **Weighing and measuring**
- **Feeding the coal into furnace.**

Transfer:

- **After preparation coal is transferred to the dead storage by means of the following systems.**
  - **Belt conveyors**
  - **Screw conveyors**
  - **Bucket elevators**
  - **Grab bucket elevators**
  - **Skip hoists**
  - **Flight conveyor**

BELT CONVEYOR

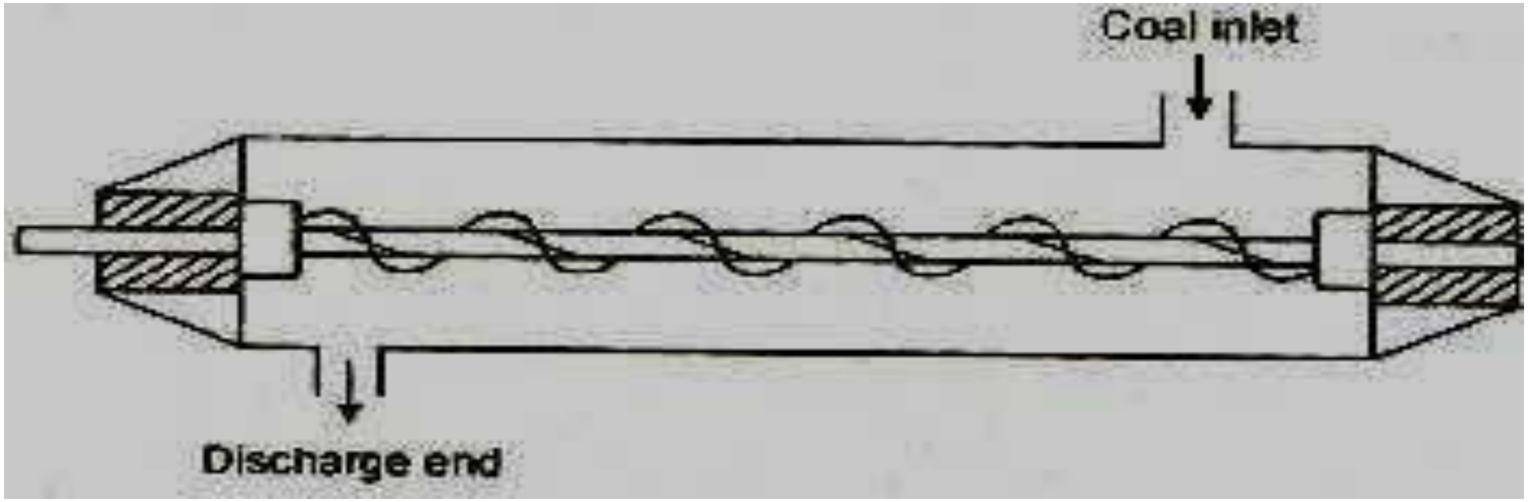


Advantages of belt conveyor:

- **It requires less power as compared to other types of systems**
- **Large quantities of coal can be discharged quickly and continuously.**
- **Material can be transported on moderate inclines.**
- **Its operation is smooth and clean**

Screw Conveyor

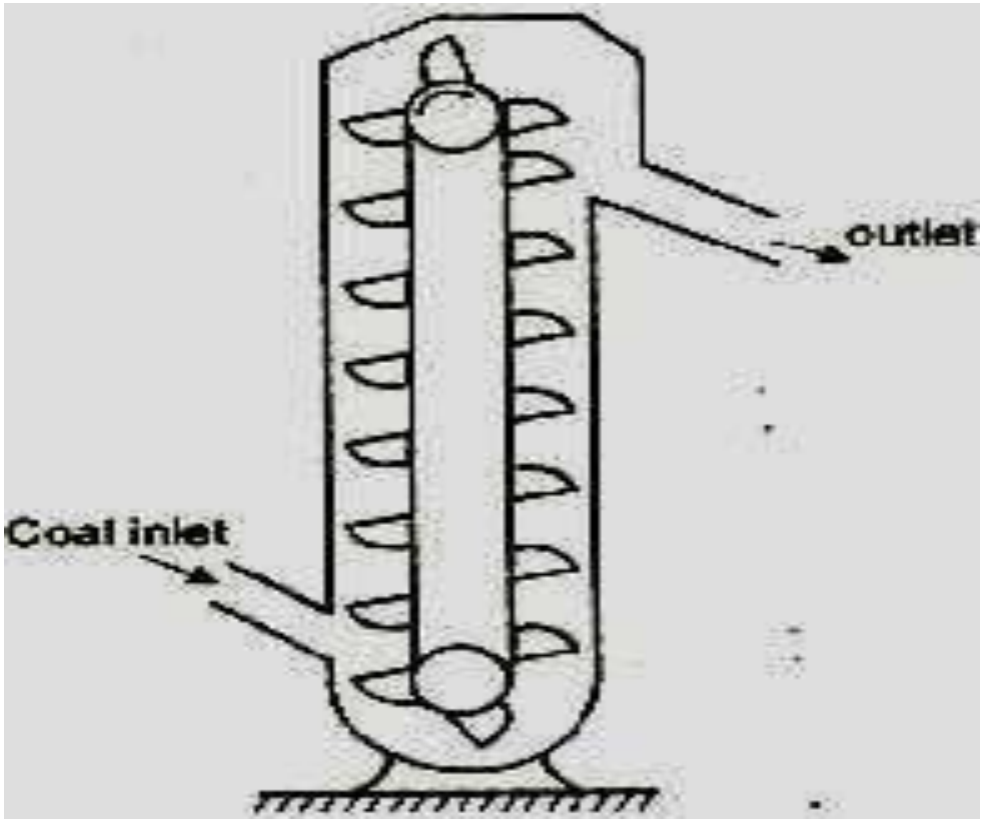
- It consists of an endless helicoid screw fitted to a shaft. The screw while rotating in a trough transfers the coal from feeding end to the discharge end.



- This system is suitable, where coal is to be transferred over shorter distance and space limitations exist.
- The initial cost of the consumption is high and there is considerable wear screw.
- Rotation of screw varies between 75-125 rpm.

Bucket elevator:

- It consists of buckets fixed to a chain. The chain moves over two wheels.The coal is carried by
- the bucket from bottom and discharged at the top.



Feed Water Treatment

Three main objectives,

- **Continuous Heat Exchange**
- **Corrosion production**
- **Production of high quality steam**

Necessity To Treat The Raw Water

- **The deposition of dissolved salts and suspended impurities will form scale on the inside wall.**
- **The harmful dissolved salts may react with various parts of boiler.**
- **Corrosion damage may occur in turbine blades**

Types Of Feed Water Treatment

1. External Treatment
2. Internal Treatment

1. Internal Treatment

a) Sodium carbonate (Soda ash) treatment

b) Phosphate treatment

c) Blow down

- Sodium carbonate reacts with sulphate and phosphate react with calcium sulphate.

2) External treatment:

a) Mechanical treatment

b) Thermal treatment

c) Demineralisation treatment

d) Chemical treatment

a) Mechanical treatment

- **Aluminium sulphate or Sodium sulphate dissolve with water**

b) Thermal treatment

- **This method mainly used for to remove the unwanted gases, like CO_2 and O_2 (up to 110 C)**

3) Demineralisation treatment

- **To remove the minerals from the water**

4) Chemical treatment

- **Added Lime and Soda ash with water to remove Magnesium And Calcium salts**

UNIT - II

DIESEL, GAS TURBINE
&
COMBINED CYCLE

- **Isentropic process** only work transfer no heat transfer.

- An **adiabatic process** occurs without transfer of heat or mass of substances between a thermodynamic system and its surroundings

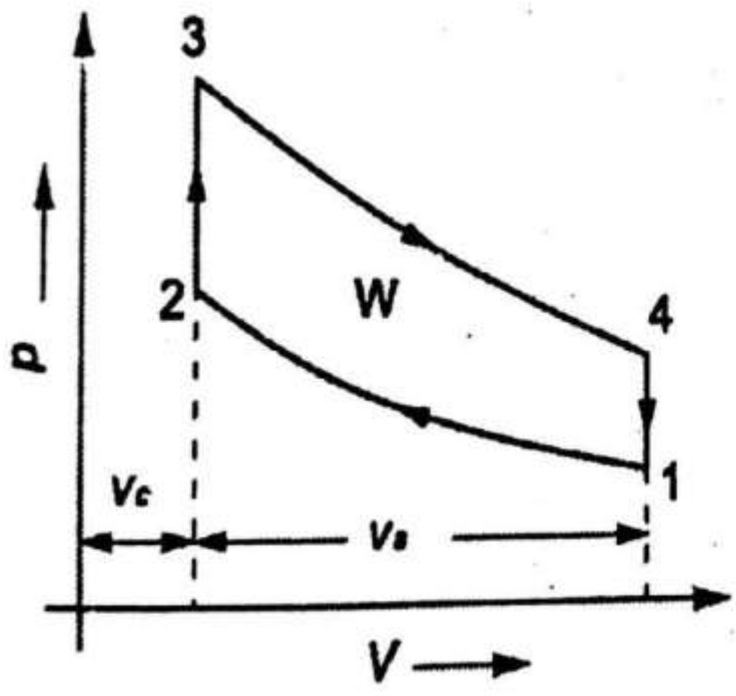
- **T-s diagram** is the type of **diagram** most frequently used to analyze energy transfer system cycles

- **Entropy** is a measure of disorder or randomness of a system. An ordered system has *low* entropy. A disordered system has *high* entropy.

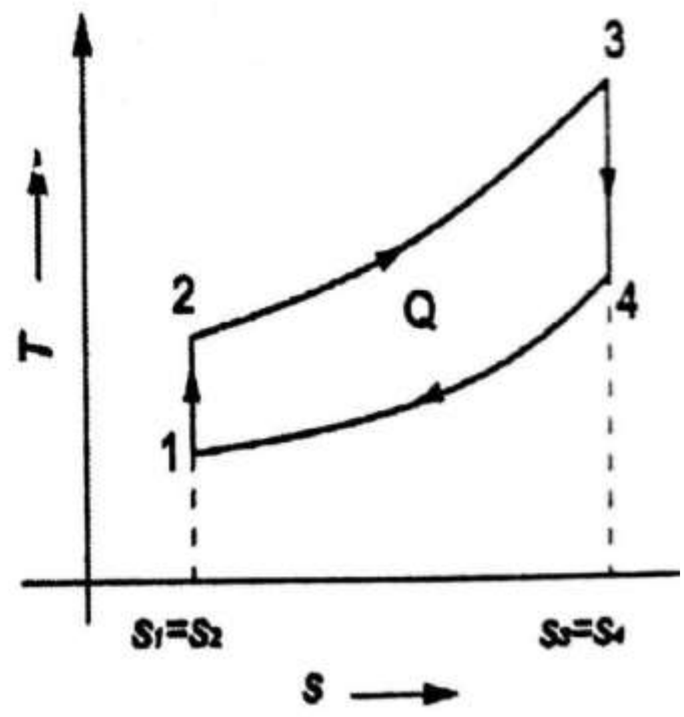
- **Enthalpy** is defined as the sum of internal energy of a system and the product of the pressure and volume of the system.

BASIC CYCLES

1) OTTO CYCLE



p-V diagram



T-s diagram

Process

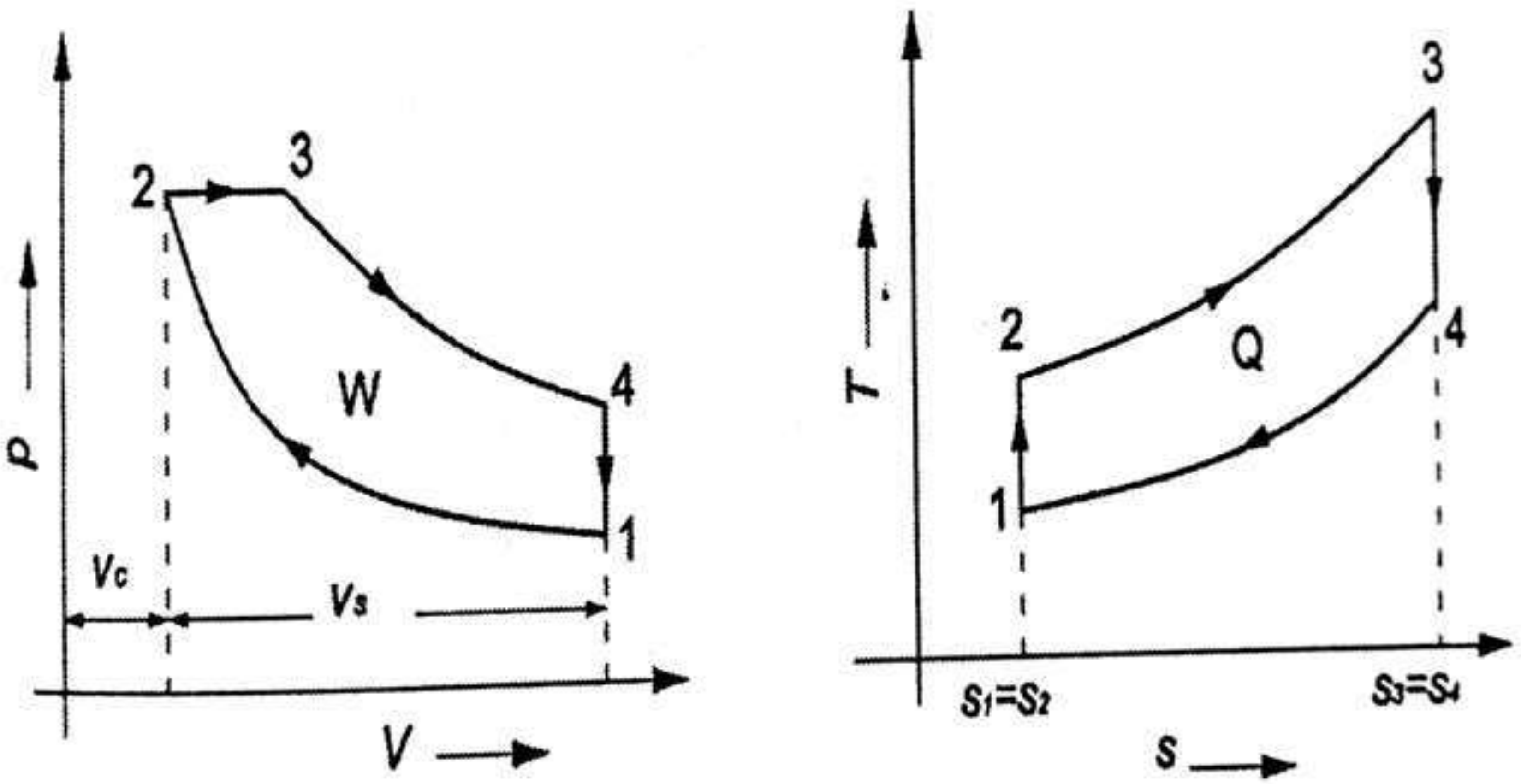
1-2 → Isentropic Compression process

2-3 → Constant Volume heat addition Process

3-4 → Isentropic Expansion process

4-1 → Constant Volume heat rejection Process

2) DIESEL CYCLE



Process

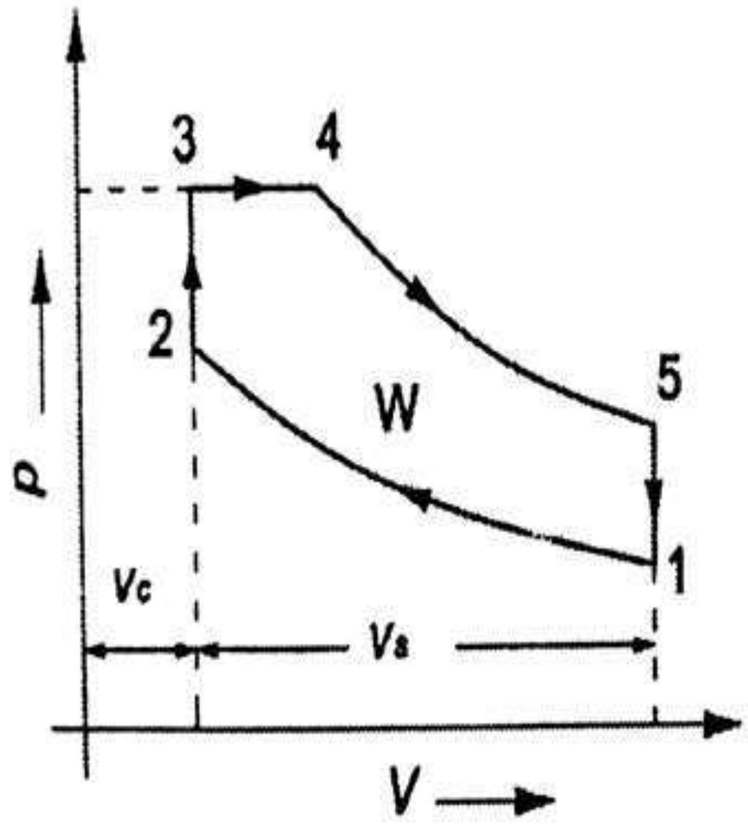
1-2 → Isentropic Compression process

2-3 → Constant Pressure heat addition Process

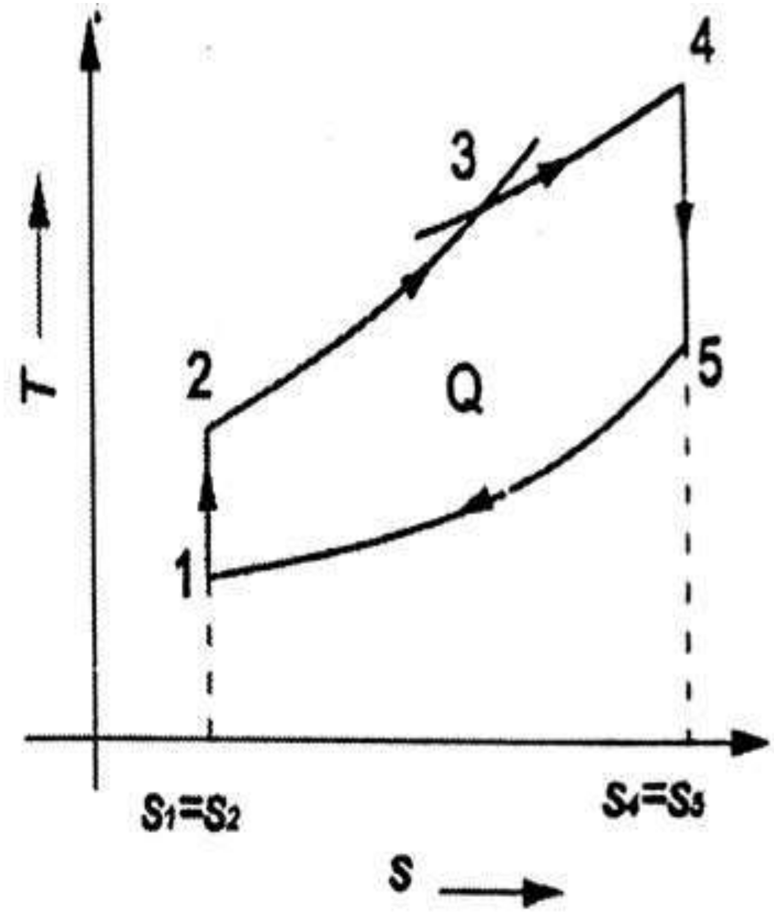
3-4 → Isentropic Expansion process

4-1 → Constant Volume heat rejection Process

3) DUAL CYCLE



p-V diagram



T-s diagram

Process

1-2 → Isentropic Compression process

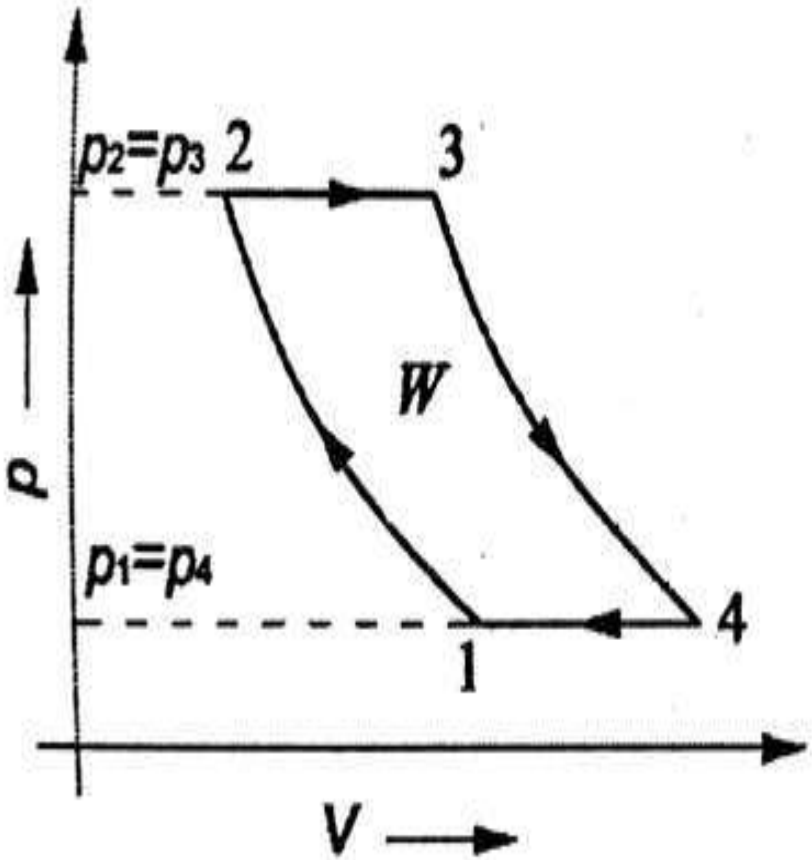
2-3 → Constant Volume Heat addition Process

3-4 → Constant Pressure Heat addition Process

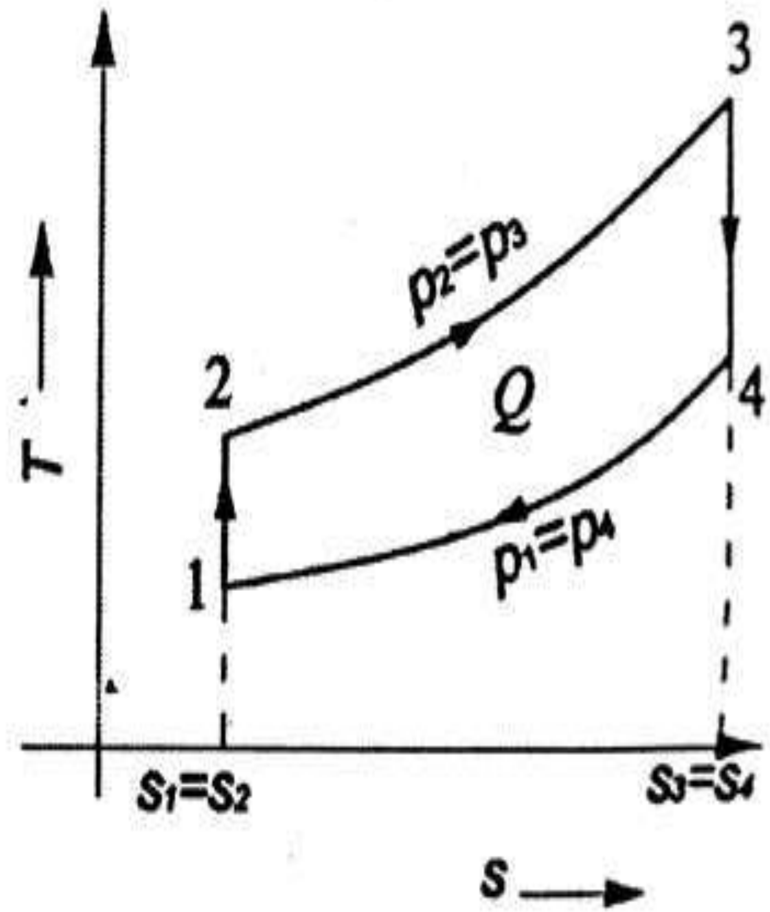
4-5 → Isentropic Expansion process

5-1 → Constant Volume heat rejection process

4) BRAYTON CYCLE



p-V diagram



T-s diagram

Process

1-2 → Isentropic Compression process

2-3 → Constant Pressure heat addition Process

3-4 → Isentropic Expansion process

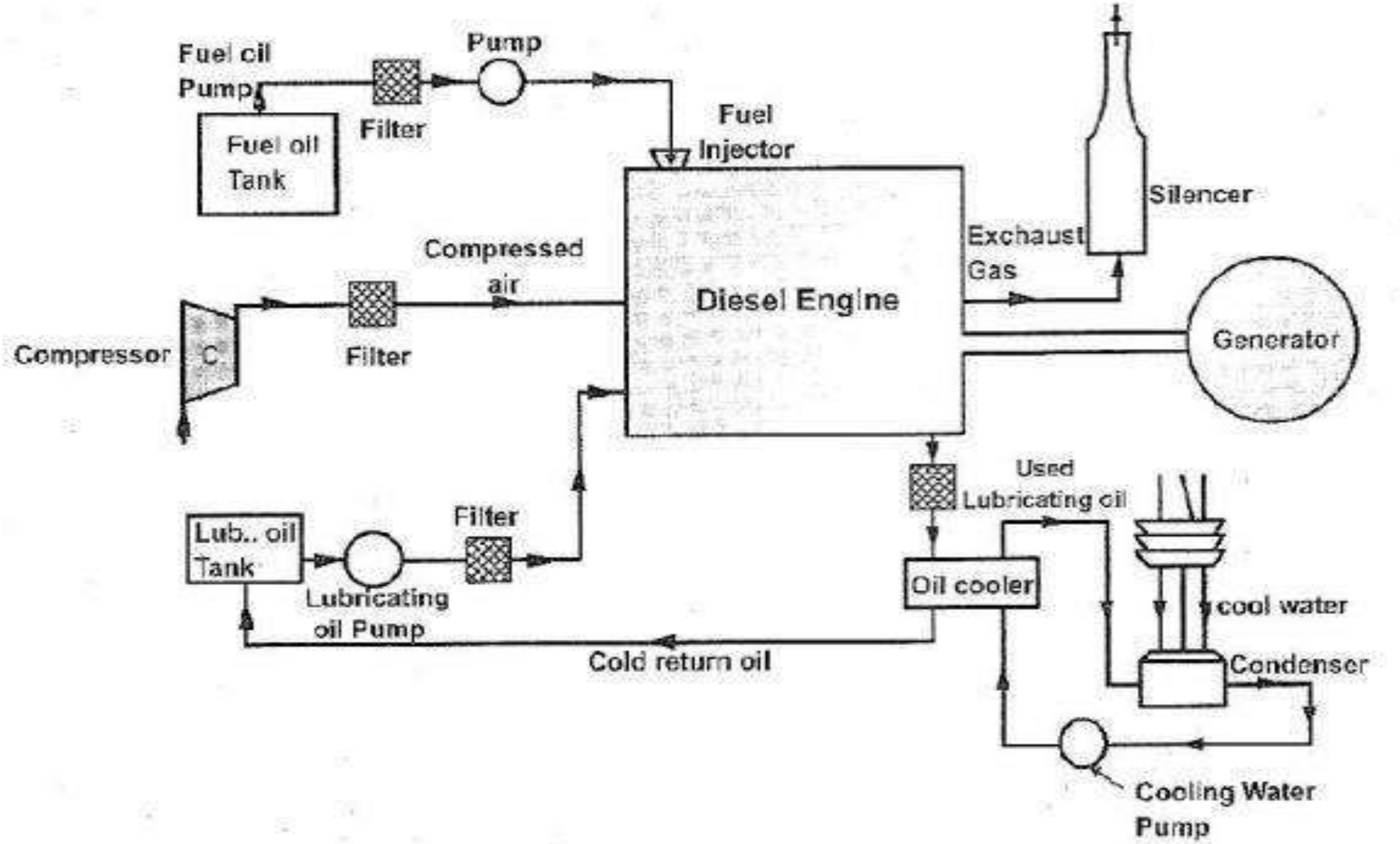
4-1 → Constant Pressure heat rejection Process

Diesel Power Plant

Essential components of a diesel power plant

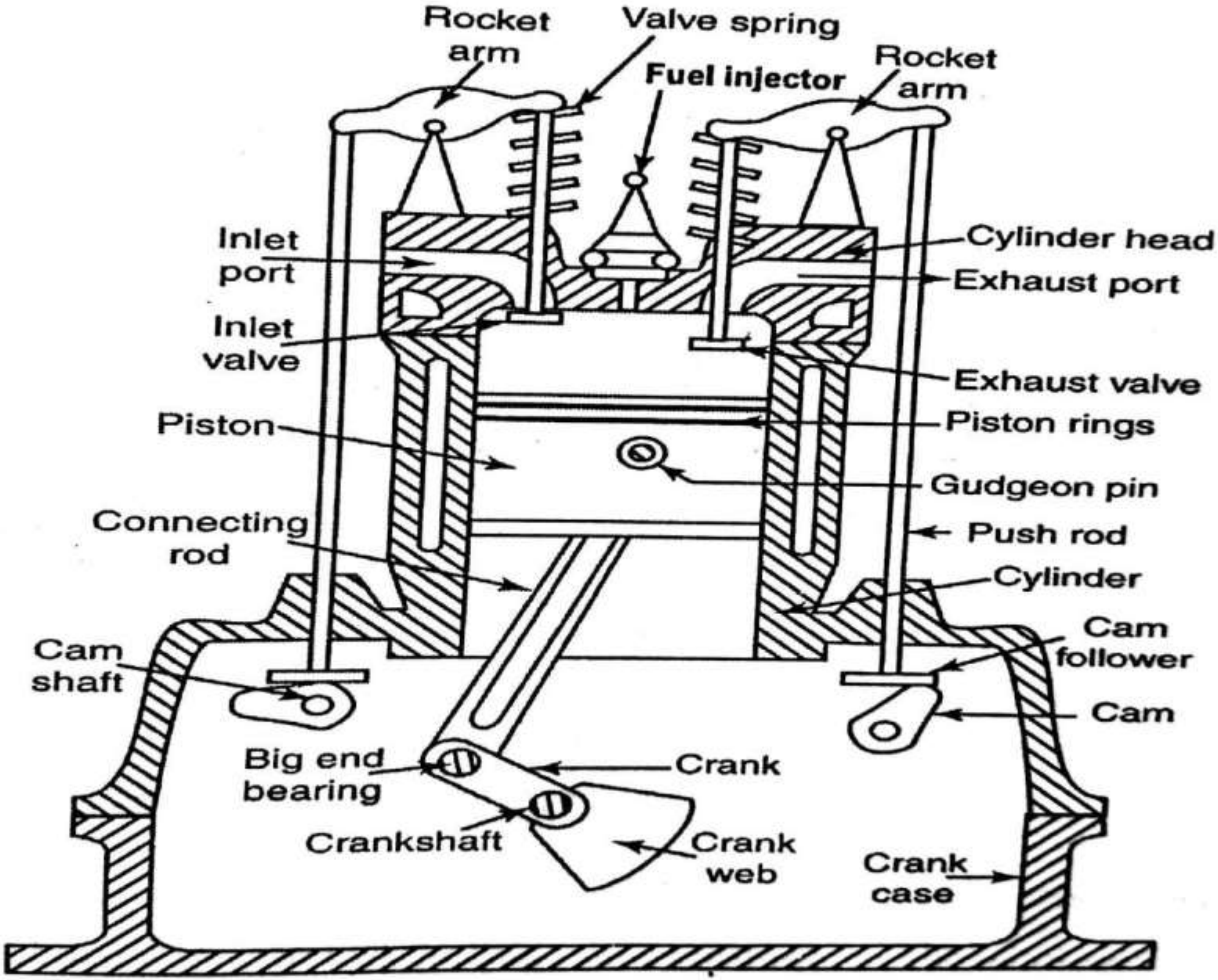
1) Engine
2) Air intake system
3) Engine starting system
4) Fuel system
5) Exhaust system
6) Cooling system
7) Lubrication system

Layout of Diesel Power plant



Major Components of engines are,

1. Cylinder head
2. Piston and cylinder assembly
3. Piston rings
4. Cam shaft
5. Crank shaft
6. Connecting rod
7. Crank case
8. Fuel Injector and FIP
9. Inlet and Exhaust valves
10. Push rod


Rocket arm
Valve spring
Fuel injector
Rocket arm
Inlet port
Cylinder head
Exhaust port
Inlet valve
Exhaust valve
Piston
Piston rings
Gudgeon pin
Connecting rod
Push rod
Cylinder
Cam shaft
Cam follower
Cam
Big end bearing
Crank
Crankshaft
Crank web
Crank case

Cooling System

Need of cooling system

1. To reduce the engine temperature.
2. To increase the engine life.

Types of cooling system

3. Air cooling
4. Water cooling
   a) Thermo-syphon cooling
   b) Pump circulation cooling
5. Liquid cooling

Thermo-syphon Cooling System

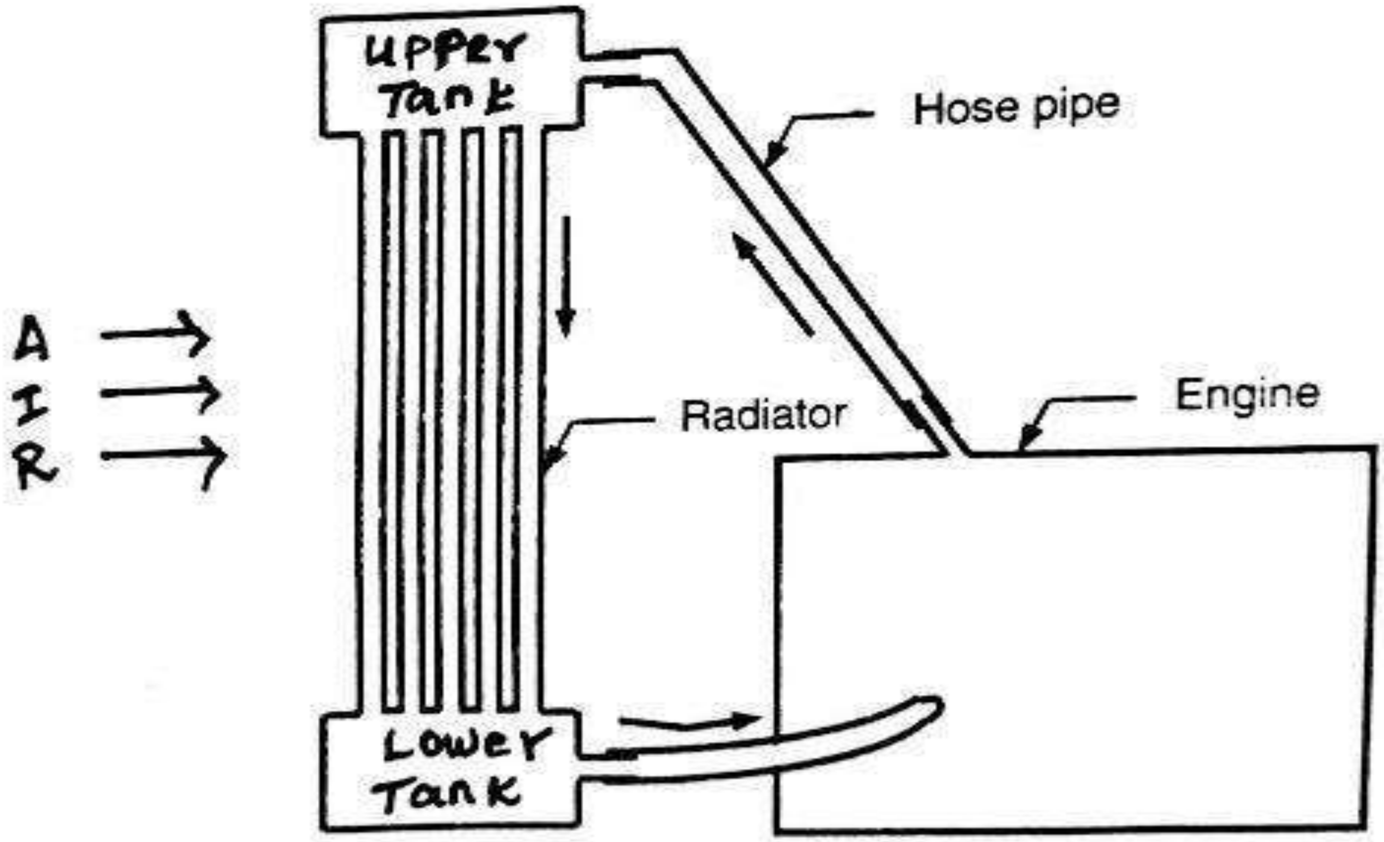


Figure 2.58 Thermosyphon system of cooling

Pump Circulation Cooling System

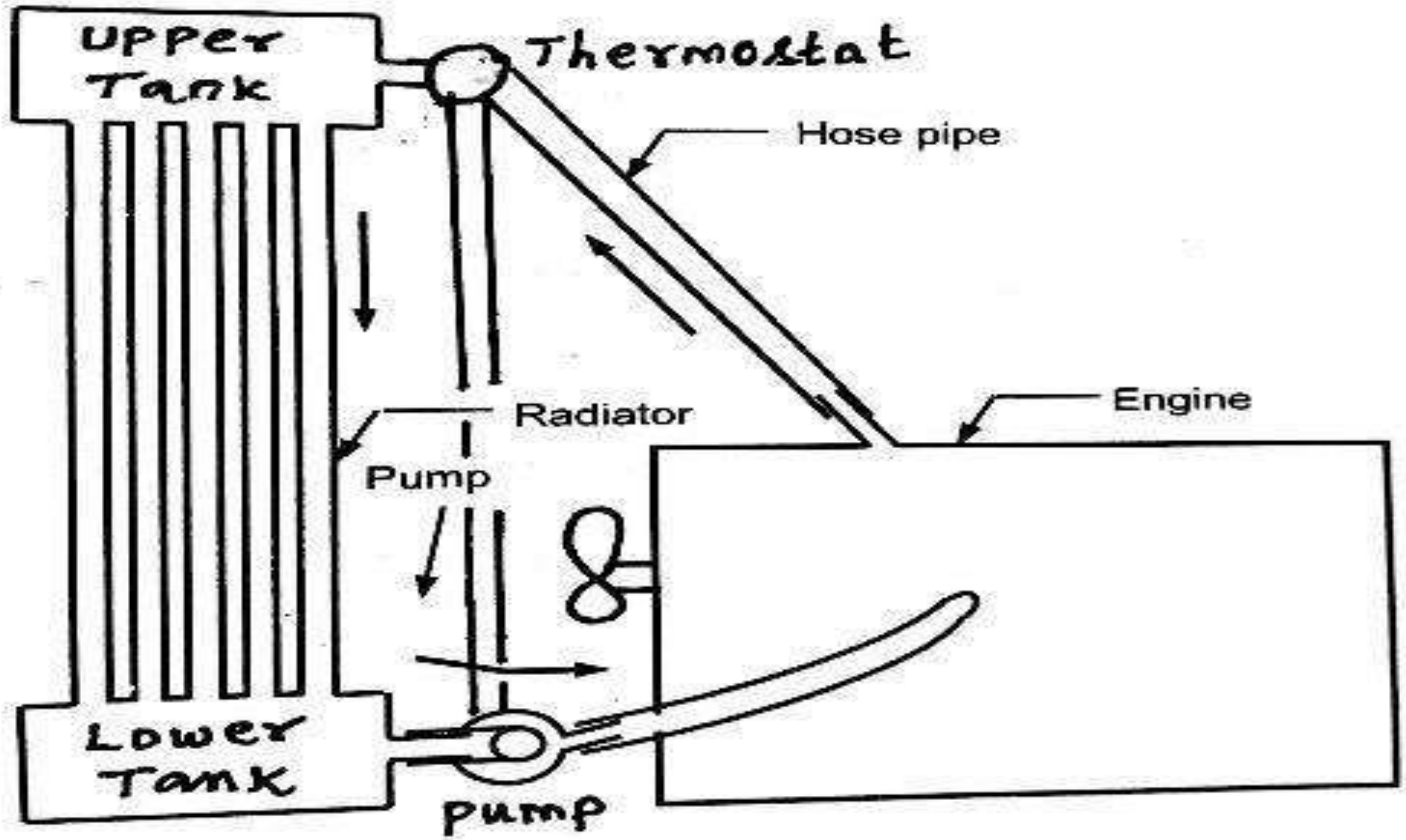


Figure 2.59 Pump circulation system

Lubrication System

Functions of lubrication

a) It reduces friction between moving parts.

b)It reduces wear and tear of the moving parts.

c) It minimizes power Loss due to friction.

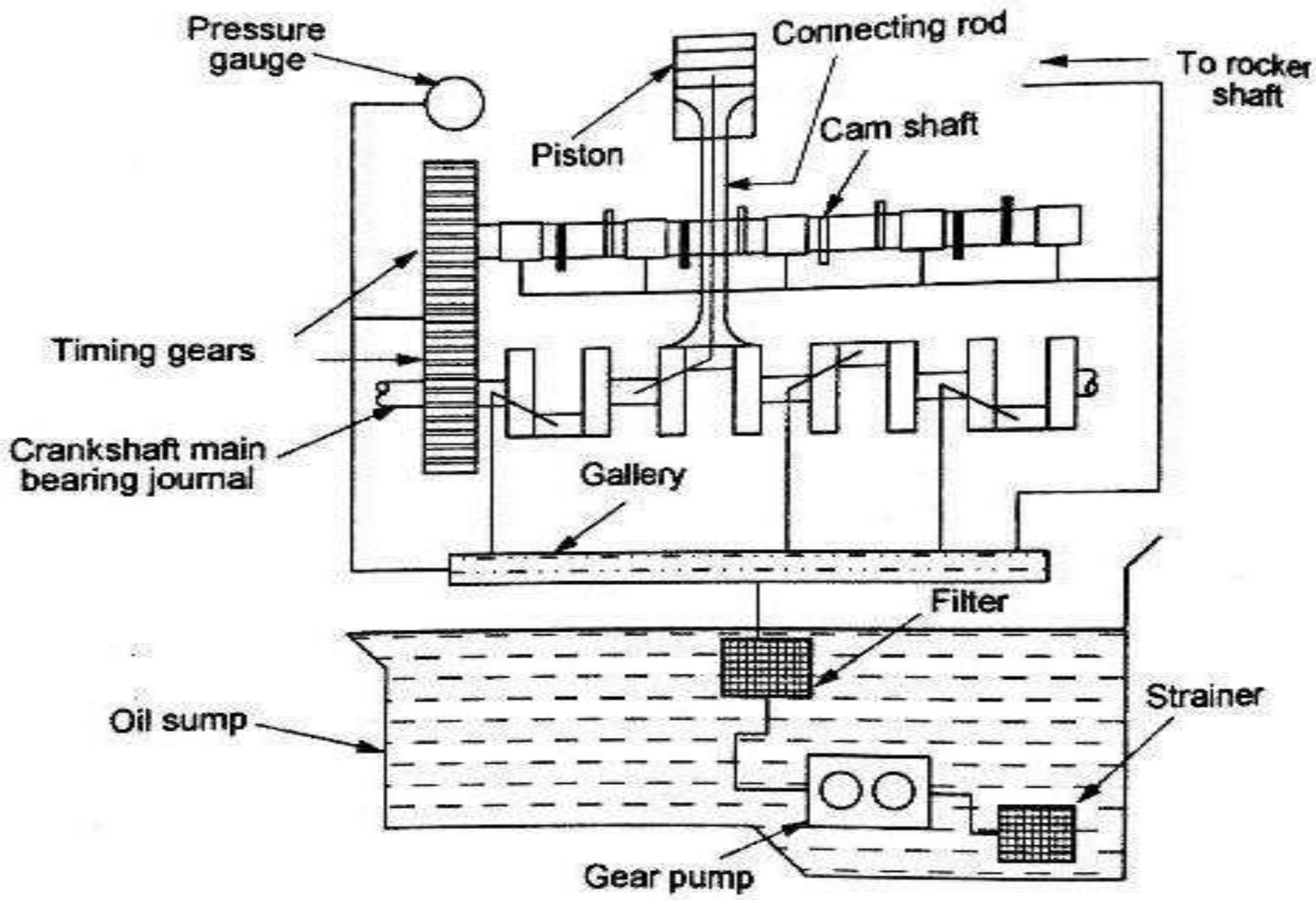
d) It reduce the heat.

e) It reduce the noise.

Types of lubrication system,

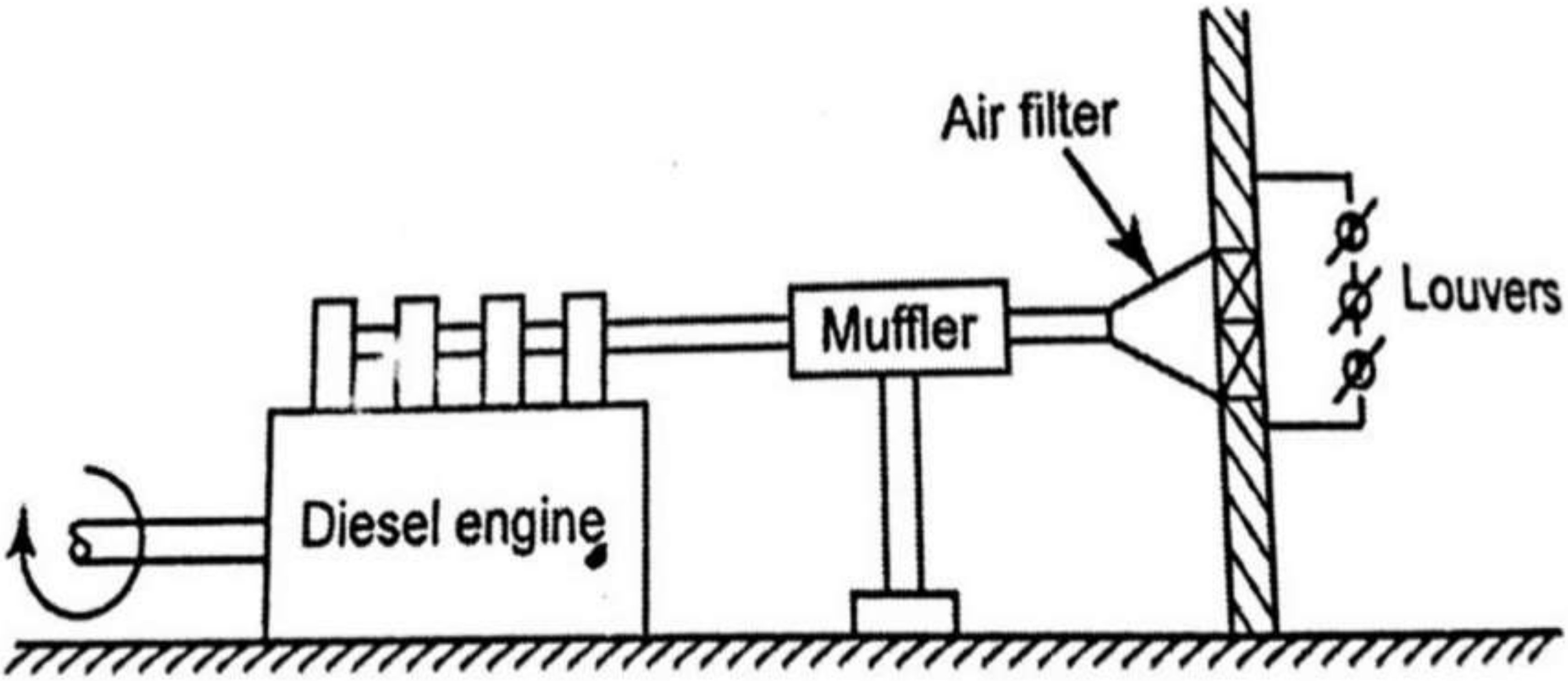
1. Petrol (or) Mist Lubrication system.
2. Wet sump system.
   a) Splash lubrication system
   b) Gravity lubrication system
   c) Pressure lubrication system
   d) Semi-pressure lubrication system.
3. Dry sump system.

Pressure Lubrication System

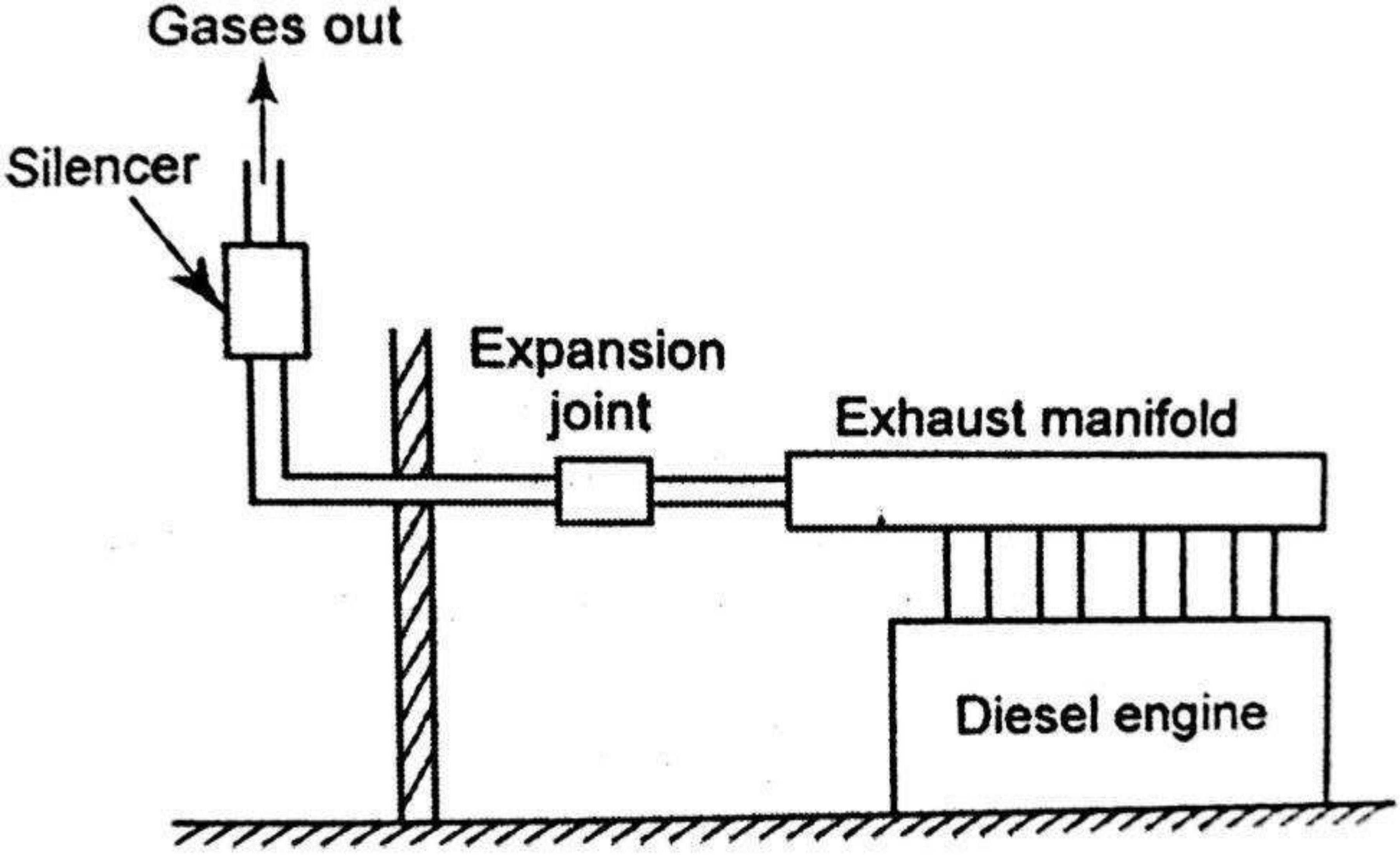


Lubrication System

Air Intake System



Exhaust system



Engine starting system

1) Starting by an auxiliary engine

2) Use of electric motors (or) Self starters

3) Compressed air system

Merits Of Diesel Power Plant

1. Diesel power plant is cheaper.
2. The plant layout is simple.
3. The location of the plant is near the load centre.
4. Skilled man power is not required.
5. It provides quick starting
6. Fuel handling is easy.
7. It occupies less space.
8. Design and installation are very simple.

Demerits Of Diesel Power Plant

1. The repair cost and maintenance cost are high.
2. The plant capacity is limited to about 50MW of power
3. The life of the diesel power plant is low
4. Diesel fuel is much more expensive.
5. The efficiency of the Diesel engine is about 33% only.

Application Of Diesel Power Plant

- **Peak load plant**
- **Mobile plants**
- **Stand by units**
- **Emergency plant**
- **Starting station**
- **Nursery station**

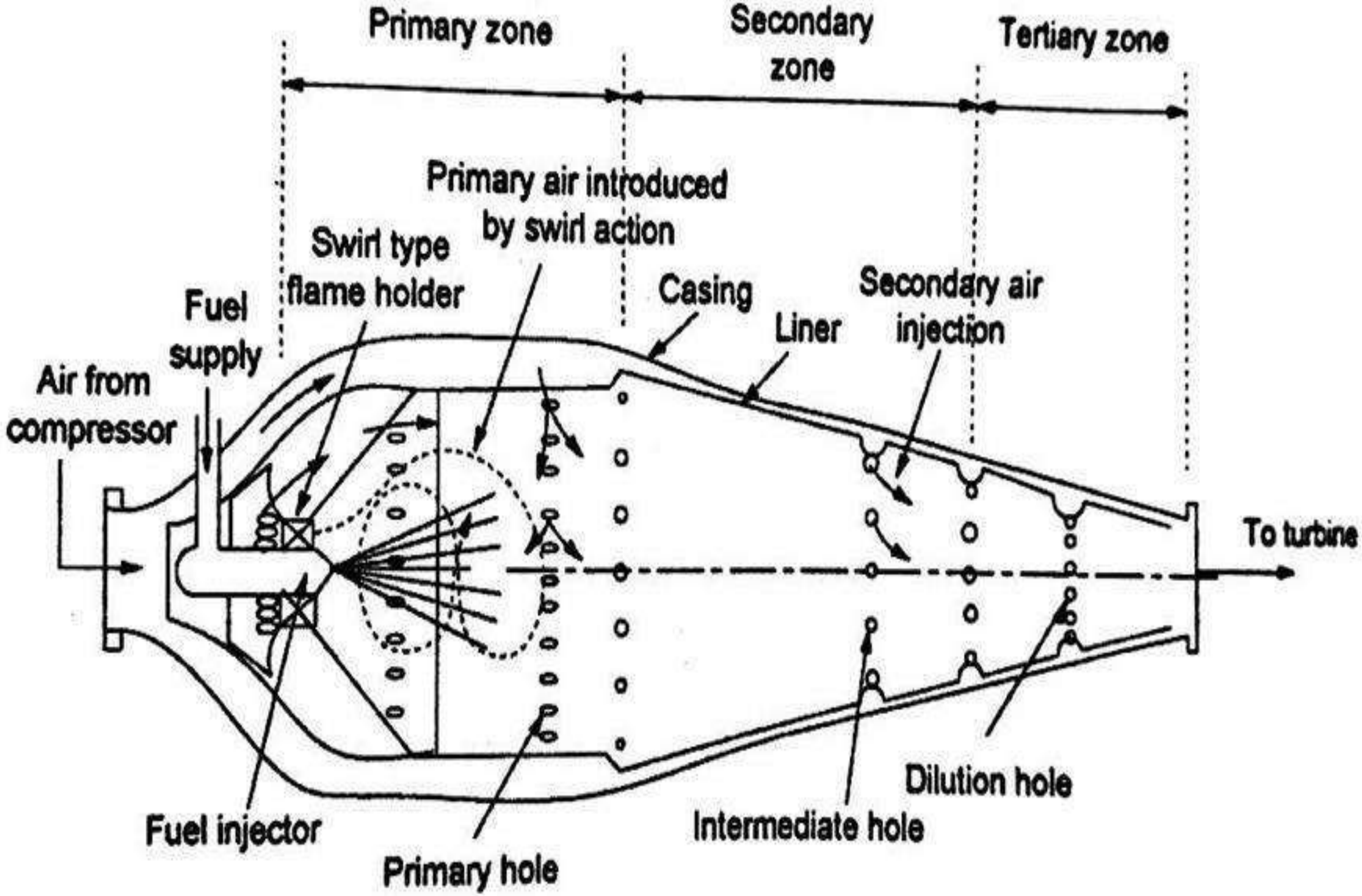
Selection Of Diesel Engine

- **Amount of fuel burned per minute**
- **Fuel Injection system**
- **Combustion processes**
- **Fuel-Air ratio**
- **Type of engine**
- **Cooling method**
- **Size of cylinder**
- **Volumetric efficiency**
- **Specific weight**

Essential Components Of A Gas Turbine

Components are,

1. Compressor
2. Combustion chamber
3. Turbine


Primary zone
Secondary zone
Tertiary zone
Primary air introduced by swirl action
Swirl type flame holder
Fuel supply
Air from compressor
Casing
Liner
Secondary air injection
To turbine
Dilution hole
Intermediate hole
Fuel injector
Primary hole

Construction details of combustion chamber:

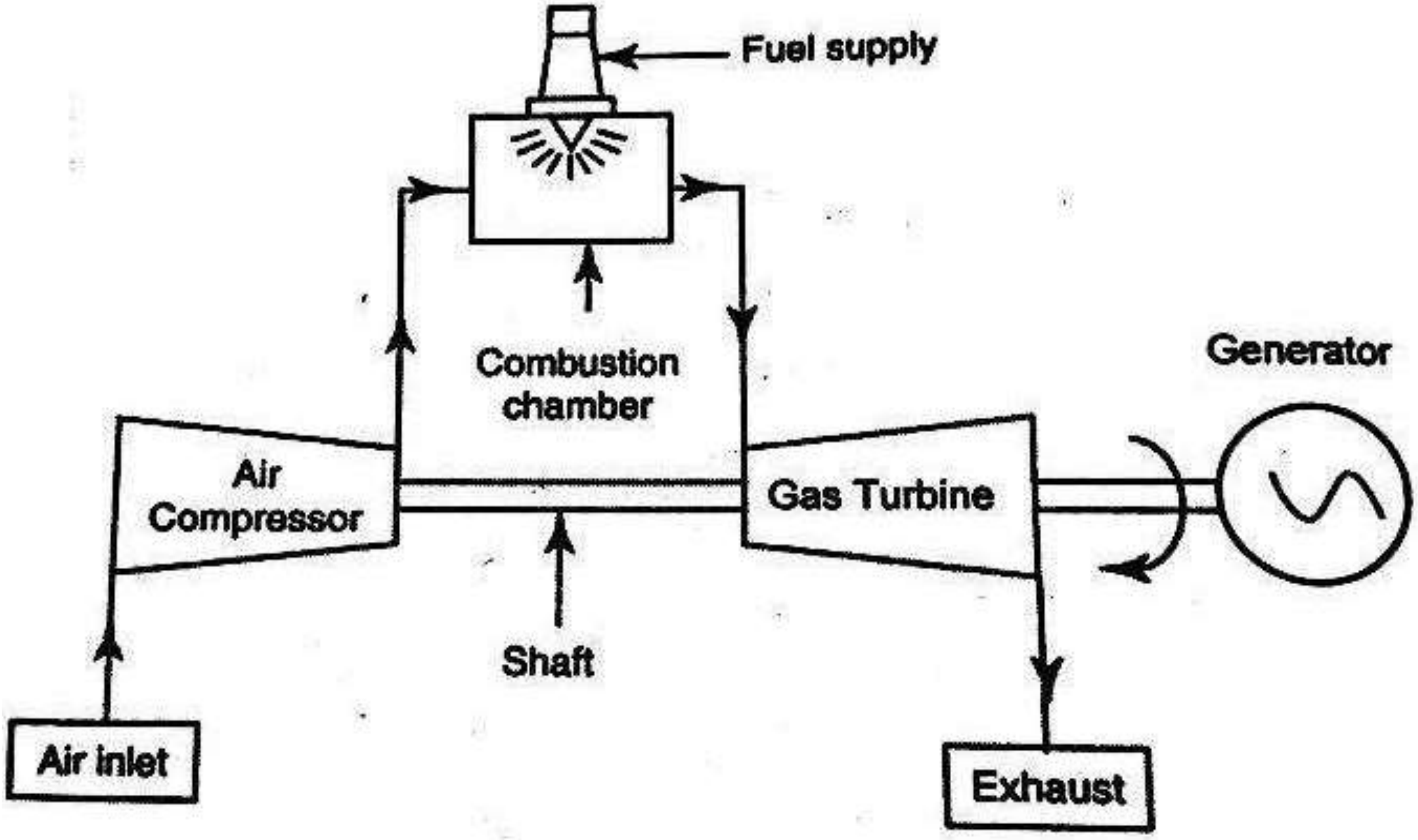
1. Case
2. Diffuser
3. Liner
4. Snout
5. Dome and Swirler
6. Fuel injector

Types Of Gas Power Plant

According to the cycle of operation it is classified into two types,

1) **Open cycle gas power plant**
2) **Closed cycle gas power plant.**

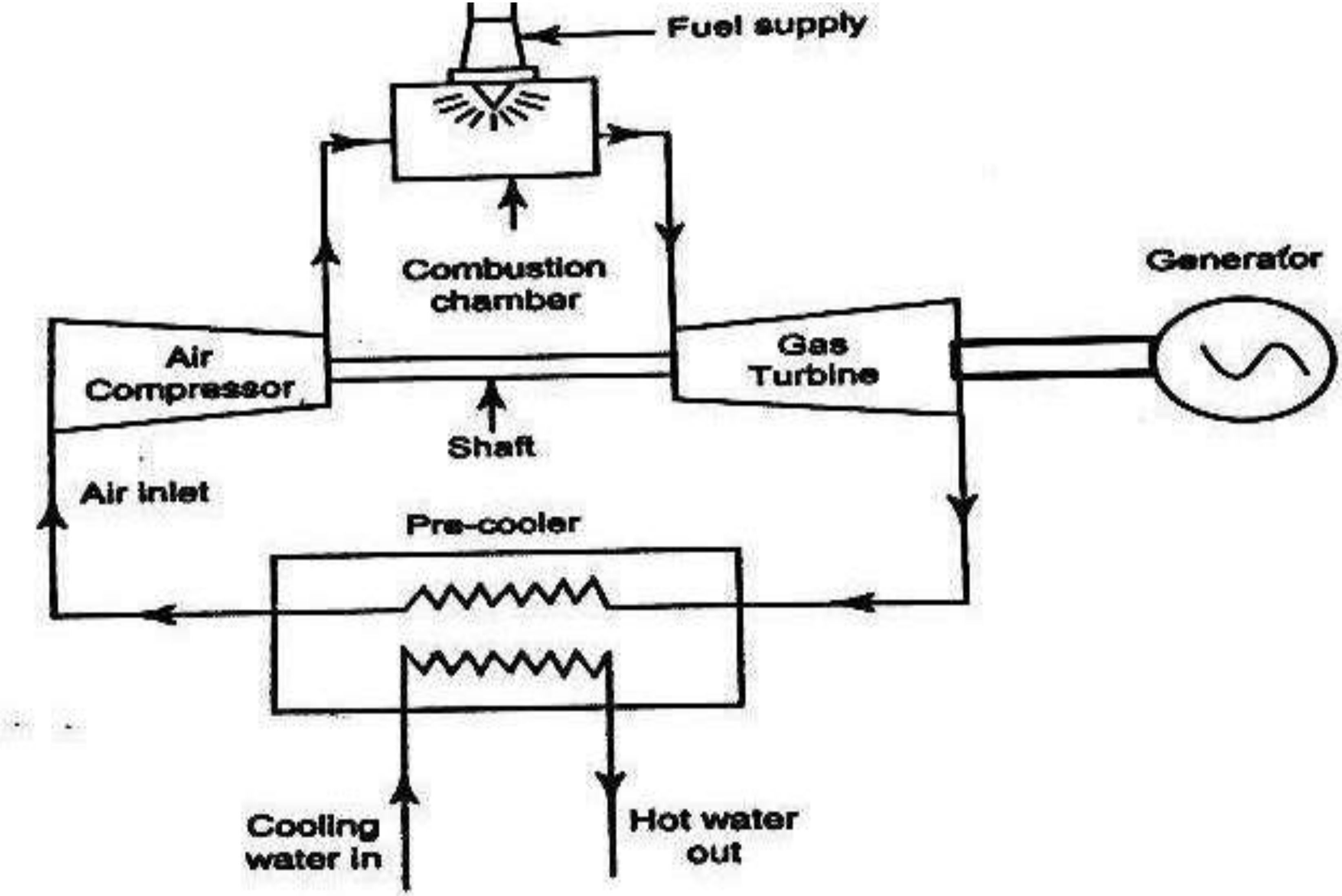
Open cycle gas power plant



Components are,

1. **Air compressor**
2. **Combustion chamber**
3. **Gas turbine**
4. **Generator**

Closed cycle gas power plant



Components are,

1. **Air compressor**
2. **Combustion chamber**
3. **Gas turbine**
4. **Generator**
5. **Pre-cooler**

Advantages of Gas power plants

1) It is smaller in size and weight
2) Natural gas is a very suitable fuel
3) It has less vibration
4) Low initial cost
5) The installation and maintenance costs are low
6) It requires less water
7) It can be started quickly.

Disadvantages of Gas power plants

1) Part load efficiency is poor

2)Major part of the work(66%) is used to drive the compressor

3)The devices that are operated at high temperature are complicated

Application

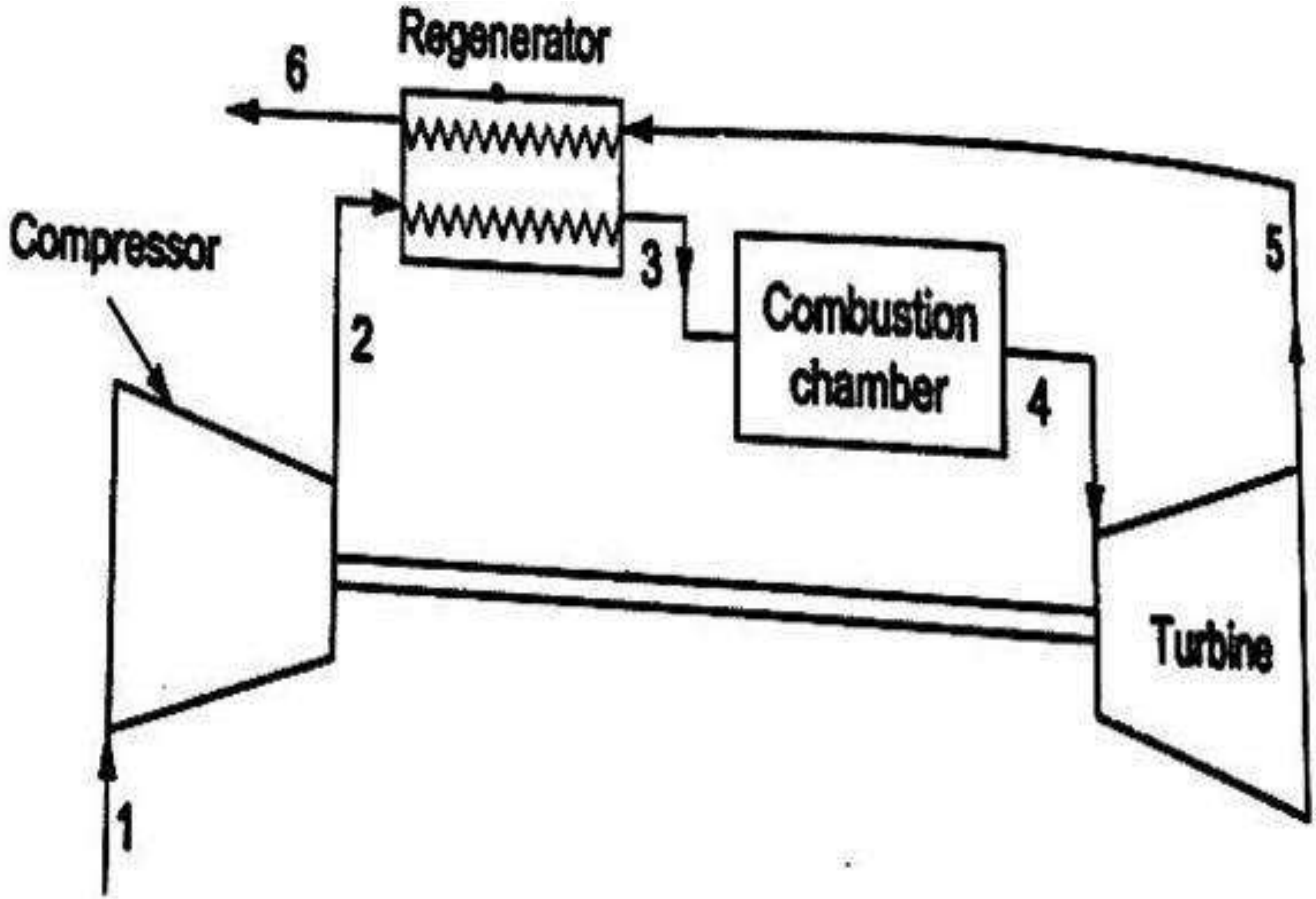
- **They are mainly used as Peak load power station,**
- **Emergency stand-by unit**
- **Hydrostatic stand-by unit.**
- **Base load power plants.**
- **The quick starting and good response characteristics**

Improvement Of Gas Power Plant

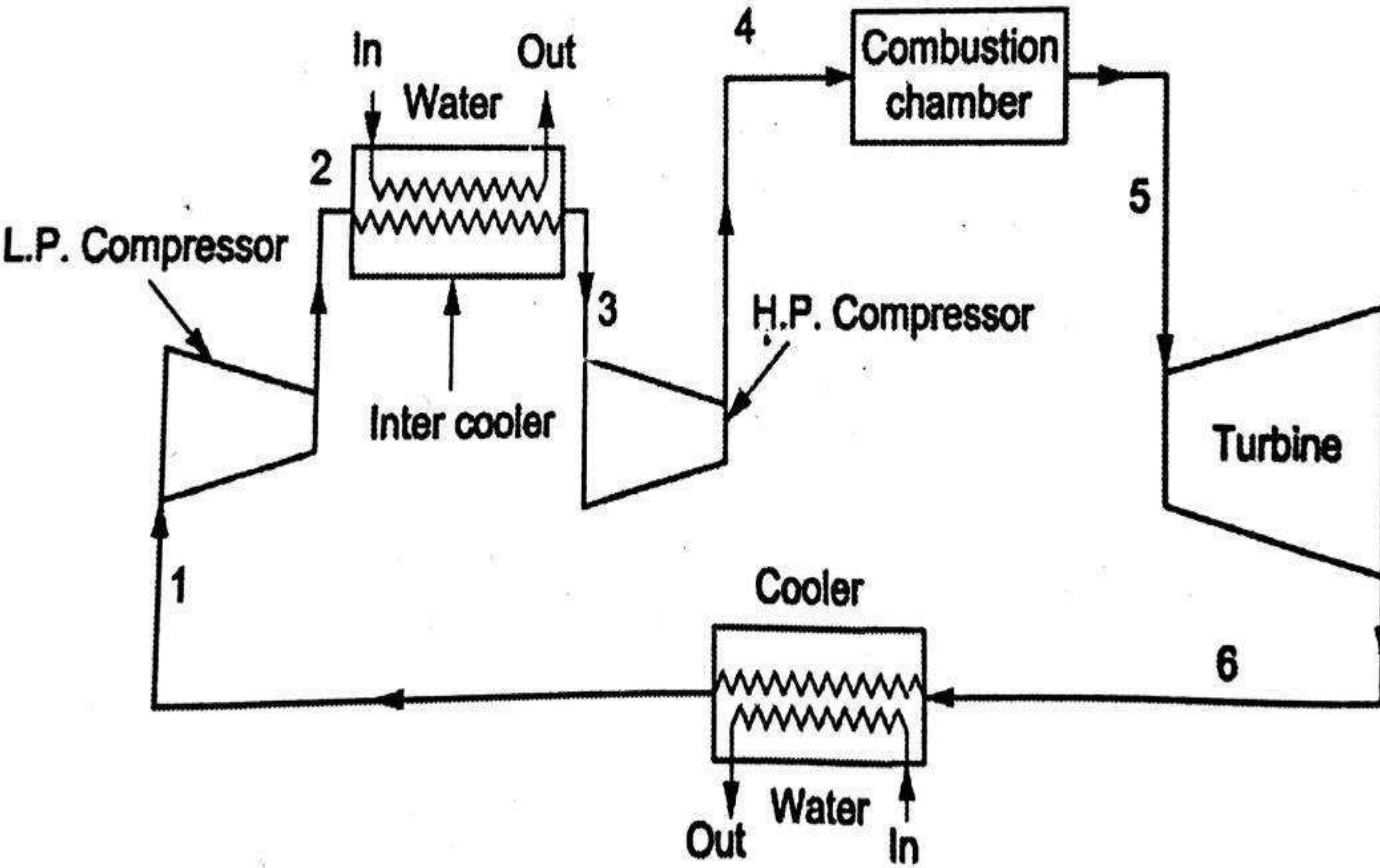
The efficiency of gas turbine power plants can be improved in four ways,

1. **Regenerator**
2. **Intercooler**
3. **Re-heater**
4. **Combined regenerator, Intercooler and re-heater**

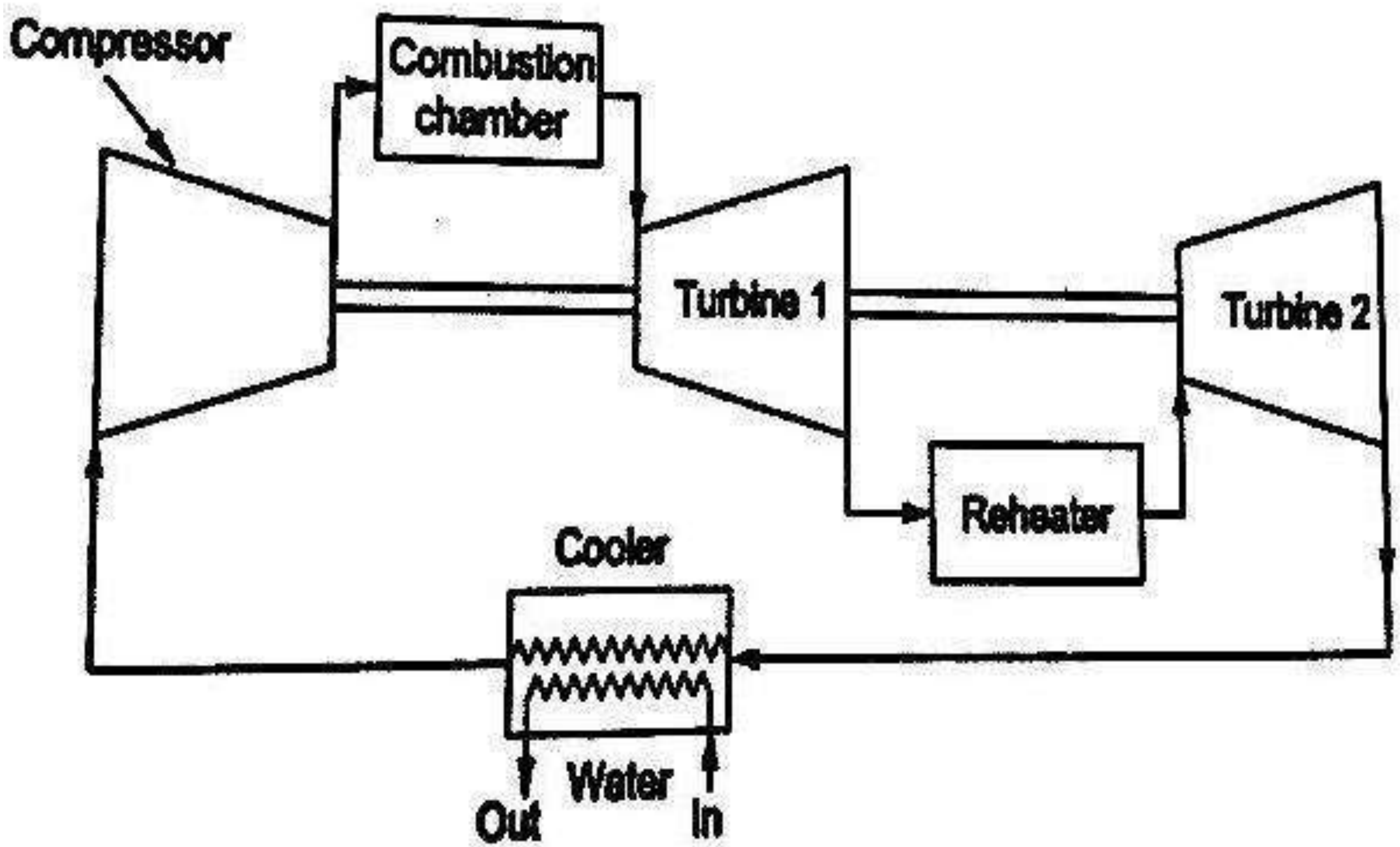
Regenerator



Intercooler



Re-heater


Compressor
Combustion chamber
Turbine 1
Turbine 2
Reheater
Cooler
Water
Out
In

Combined Power Plant

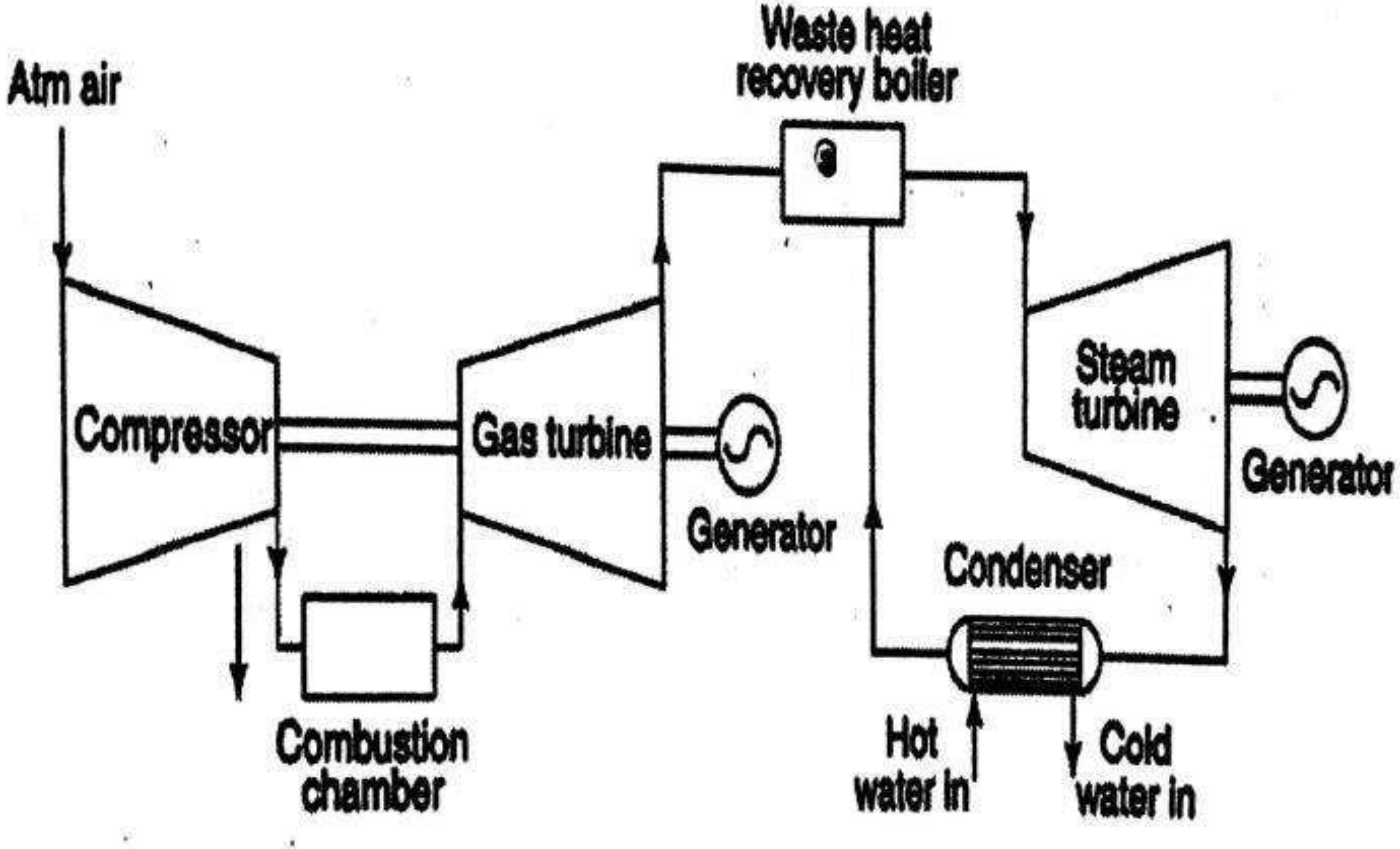
Combined Power Plant

- **The maximum steam temperature in a power cycle exceeds 600 C but the pulverized coal furnace temperature is about 1300 C.**
- **So, there is a lot of energy wasted in the power plant.**
- **To increase the efficiency and reduce the fuel consumption, the combined power cycles are introduced.**

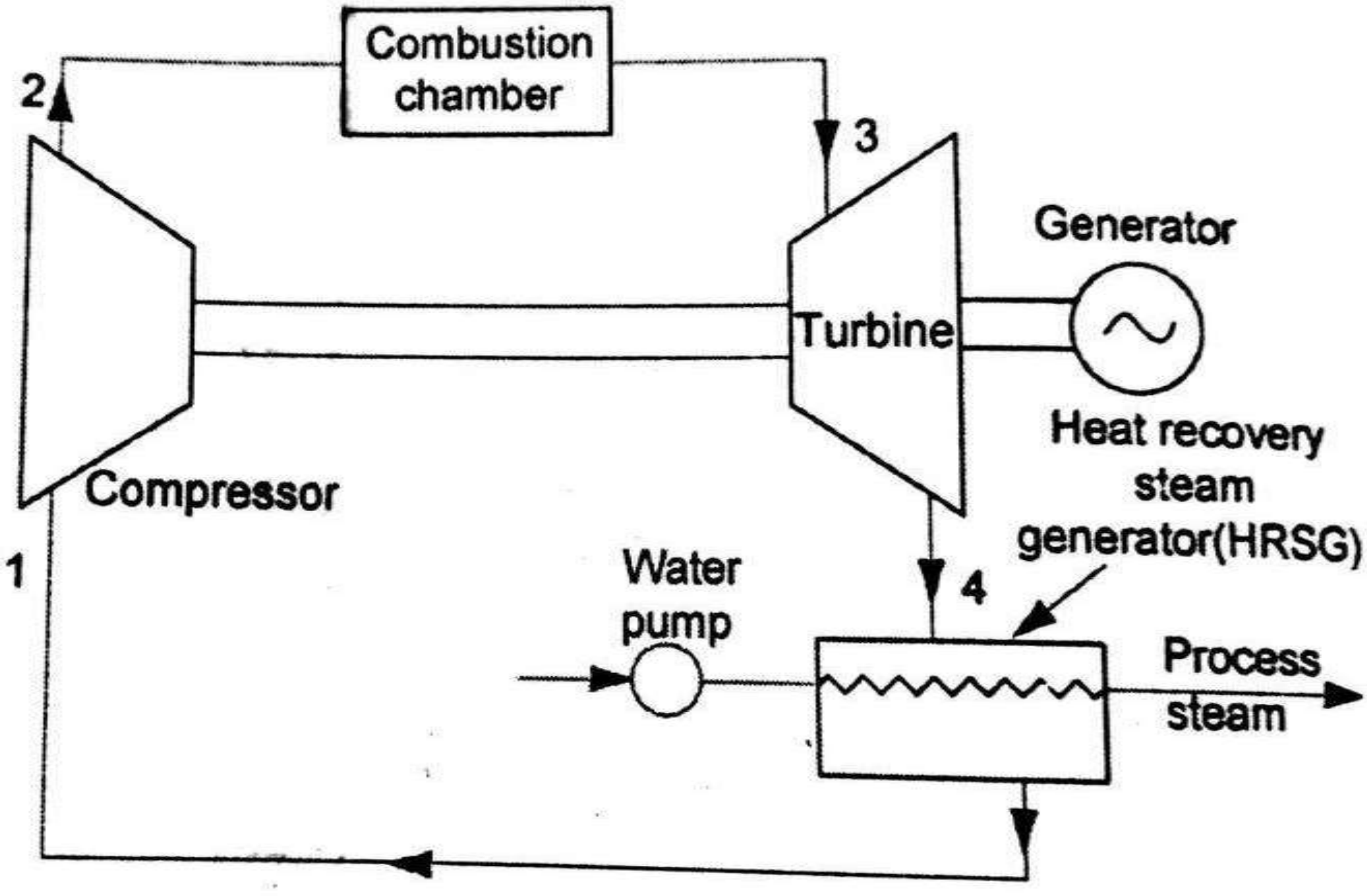
Types of combined power cycle:

1. Gas turbine – Steam turbine power plant.
2. Combined gas turbine and co-generation power plant
3. Combined gas turbine and diesel power plant
4. Nuclear – Steam combined power plant.

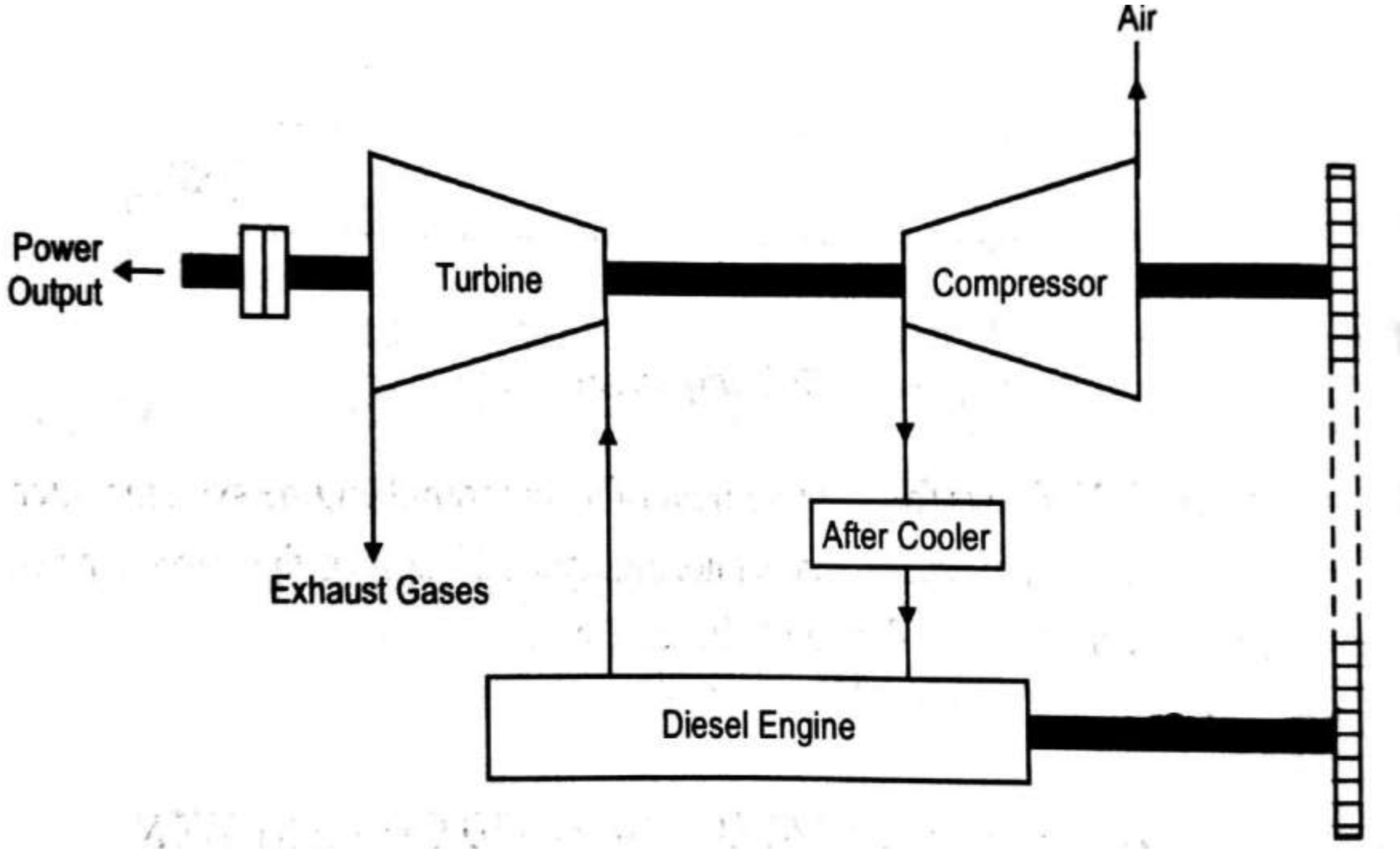
1) Gas Turbine – Steam Turbine Power Plant



2) Combined Gas Turbine And Co-generation Power Plant



3) Combined gas turbine and diesel power plant



Integrated Gasification Combined Cycle (IGCC)

IGCC plant consists of the following four major units:

1. **Air separation Unit (ASU)**

   ASU supplies Oxygen and steam required for gasification

2. **Gasification system**

   The unit has a coal Gasifier where the conversion of solid fuel into combustible syngas takes Place.

3. **Gas clean-up**

   It filters the impurities in syngas

4. **Combined power block**

   It consists of a steam turbine and gas turbine for power production.

IAE – I

1) Layout of thermal power plant

2)High pressure boiler(La-Mont, Benson, Loeffler and Velox)

3)Super critical boiler(Drum type, once through boiler)

4) Fluidized Bed Combustion(FBC)

5) Fluidized Bed Boilers(BFB & CFB)

6) Ash handling system

7) Coal handling system

8) Surface condenser

9) Types of stokers

10) Draught systems

11) Types of Co-generation

12) Binary cycle

13) Cyclone separator, Electro static precipitator (ESP)

14) Types of cooling tower(Hyperbolic cooling tower)

15) Feed water treatment

UNIT- II

1) PV & TS diagram and process
2) Layout of diesel power plant
3) Air intake system & Exhaust system
4) Main components of Gas power plant
5) Types of gas power plant
6) Types of combined power plants
7) How to improve the efficiency of Gas power plant(Regenerator, Re-heater & Intercooler)
8) Integrated Gasification Combined Cycle(IGCC)

UNIT- III

NUCLEAR POWER PLANTS

S.NO	FUEL	Percentage
1	Petroleum	39%
2	Natural gas	24%
3	Coal	22%
4	Hydro power	6.9%
5	Nuclear	6.3%

Indian Nuclear Power Plants

Power station	Operator	Establishment Date	Location	District	State	Reactor Units (MW) (including under constructio)	Installed Capacity (MW)
Tarapur Atomic Power Station	NPCIL	October 28, 1969	Tarapur	Thane	Maharashtra	2 x 160, 2 x 540	1,400
Kakrapar Atomic Power Station	NPCIL	May 6, 1993	Kakrapar	Surat	Gujarat	2 x 220, 2 x 700	440
Western					2	8	1,840

Kudankulam Nuclear Power Plant	NPCIL	October 22, 2013	Kudankulam	Tirunelveli	Tamil Nadu	4 x 1,000	2,000
Kaiga Nuclear Power Plant	NPCIL	November 16, 2000	Kaiga	Uttara Kannada	Karnataka	4 x 220	880
Madras Atomic Power Station	NPCIL	January 24, 1984	Kalpakkam	Kancheepuram	Tamil Nadu	2 x 220, 1 x 500	440
Southern					3	11	3,320

Elementary Theory

Atomic structure

An element is defined as a substance which cannot be decomposed into the other substance.

The smallest particle of an element which takes a part in chemical reaction is known as ‘Atom’

Atomic number

The number of protons in the nucleus is atomic number, it is denoted by ‘’z’

Mass number

The total number of nucleons in the nucleus is called mass number, it is denoted by ‘’A’

The difference between mass number and atomic number gives the number of neutrons

Isotopes:

Some elements exists in different forms,

The mass number is different but the atomic number is same

Nuclear binding energy:

The energy released at the moment of combination of two nucleons to form nucleus an atom is called binding energy.

It is represented by electron volt (eV)

One electron volt = 1.602×10^{-9} KJ

Atomic mass unit

The ‘’amu” is a unit of mass approximately 1.66 x 10^{-24} kg

Radioactivity

Radioactivity is the phenomenon of spontaneous emission of powerful radiations exhibited by heavy elements.

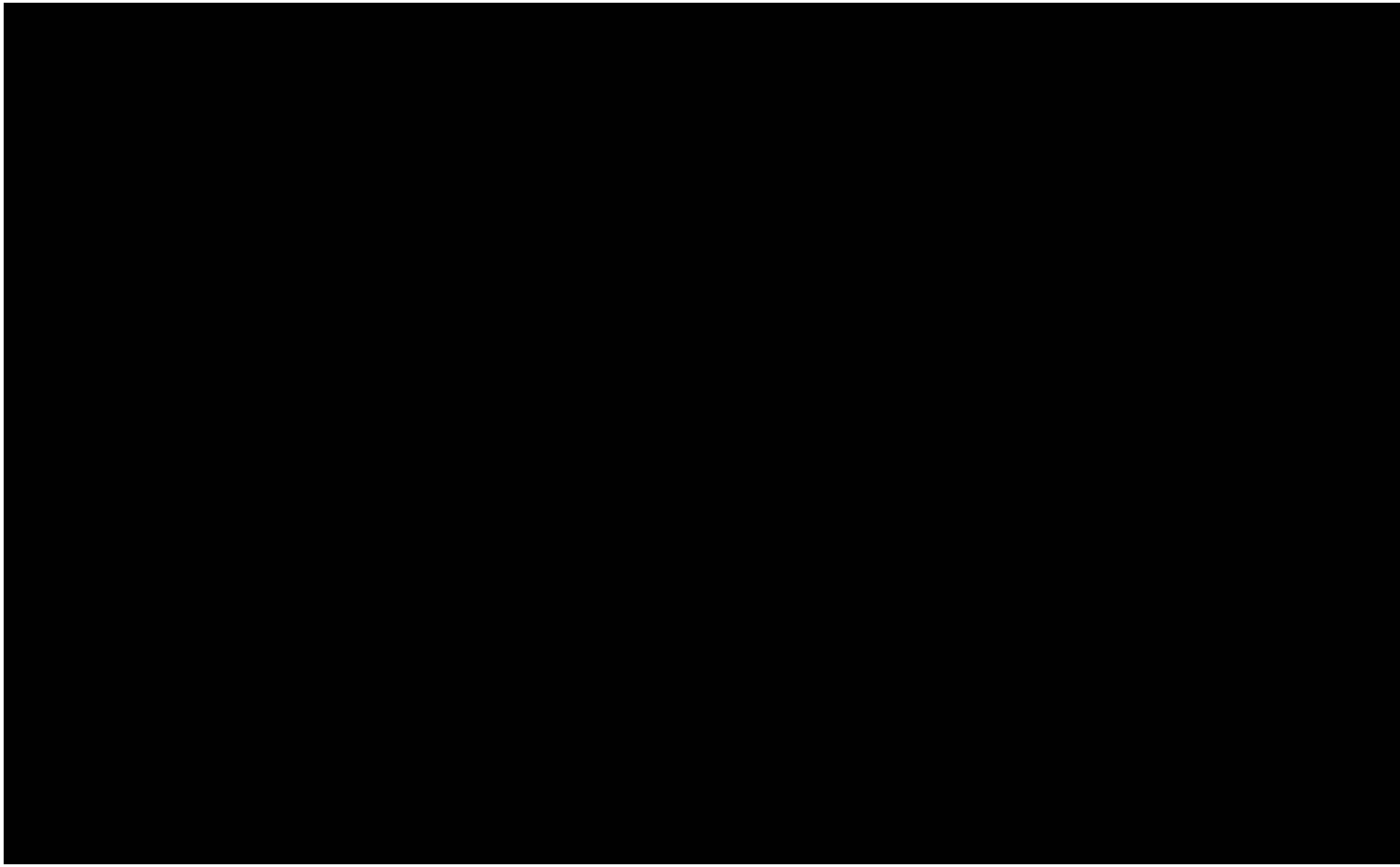
Half -life

The radioactive half-life for a given radioisotope is a measure of tendency of nucleus to ‘’Decay’ and it is purely based on the probability

Name	Half life
Carbon-14	5730 years
Sodium-24	15 Hours
Iron-59	45 Days
Cobalt-60	5.3 years
Uranium-235	710 Million years

Chernobyl disaster

Chernobyl disaster effects



Nuclear Fuels

Fissile fuels:

U^{233}, U^{235} (Naturel) and PU^{239}

Fertile fuels:

It can be converted to fissionable materials,

PU^{239} ------------------ U^{238}

U^{233} ------------------ Th^{232}

Multiplication factor:

$$K = \frac{\text{Number of neutrons in any particular generation}}{\text{Number of neutrons in the preceding } \textit{generation}}$$

Nuclear Fission:

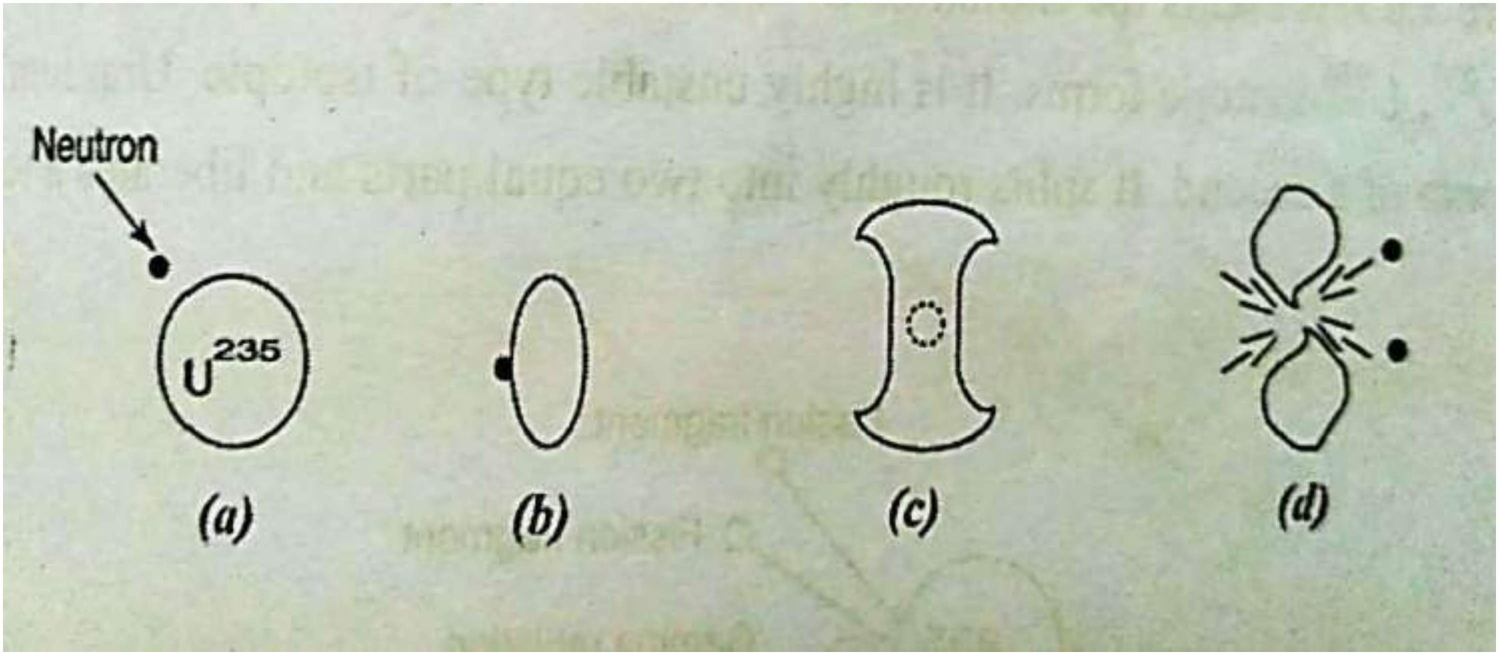
- **It is the process of splitting the unstable heavy nucleus into two fragment of approximately equal mass when bombarded with neutrons.**

a) Pre fission stage

b) Distorted stage

c) Excited stage

d) Post fission stage

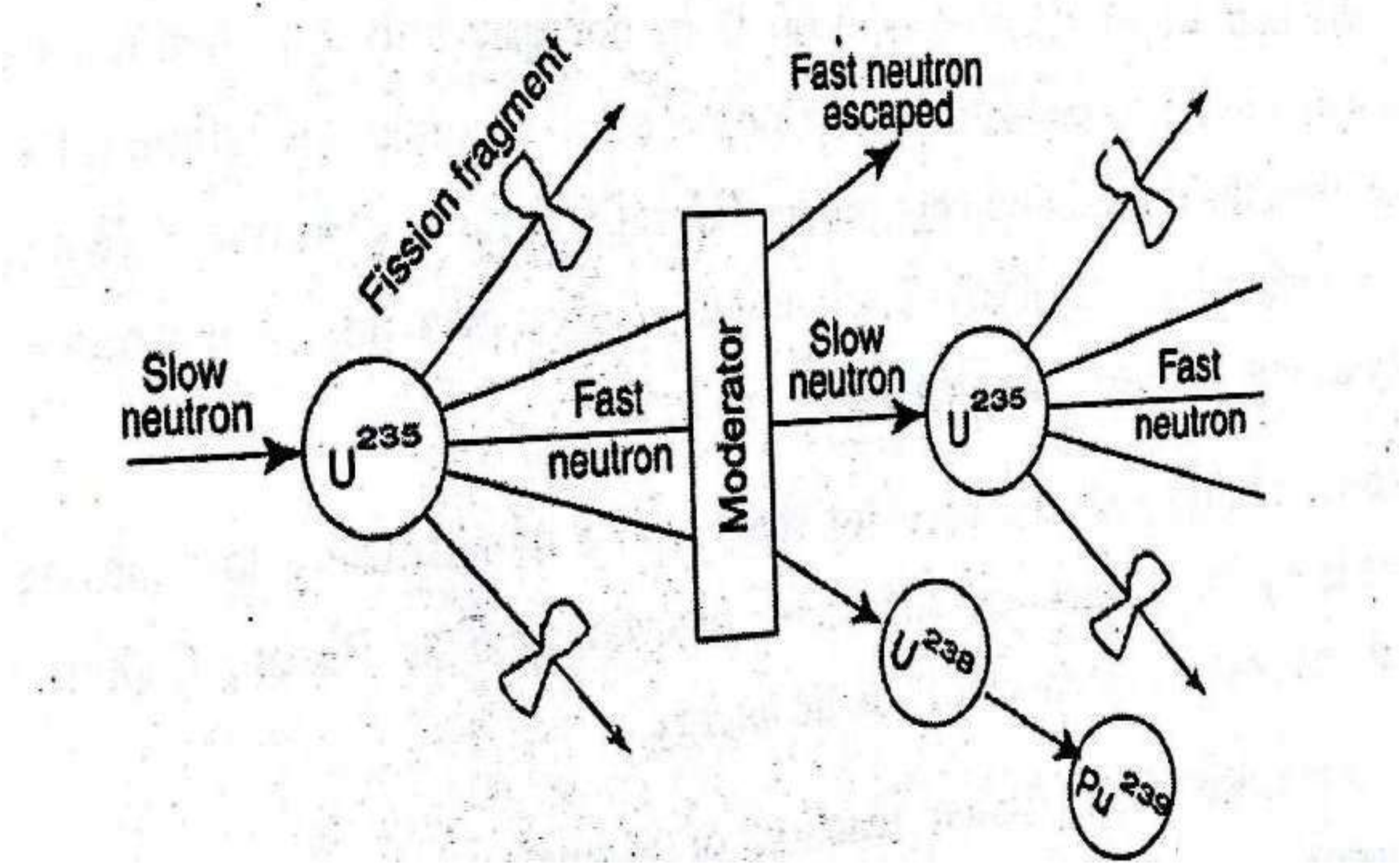


Nuclear Fusion:

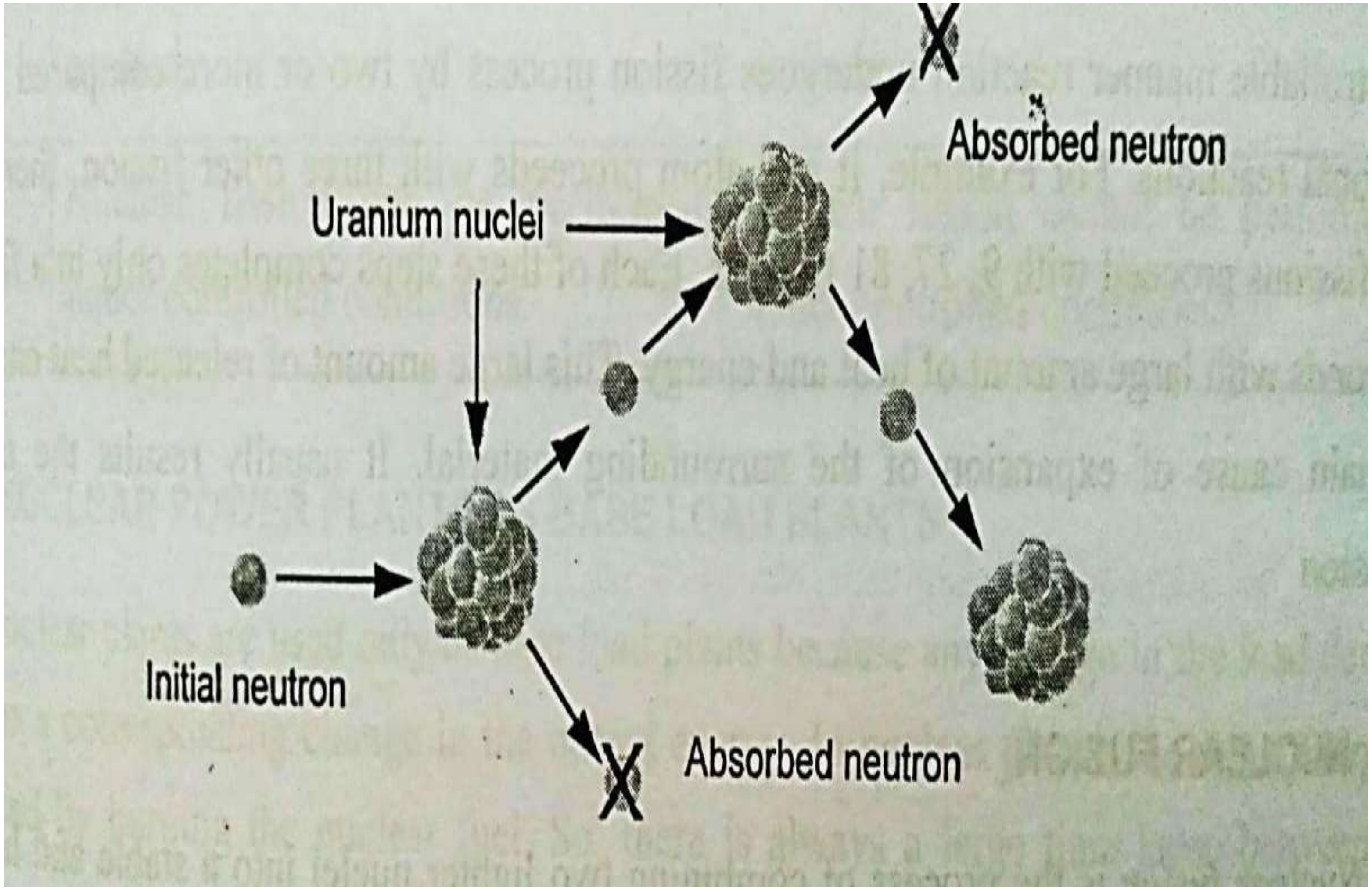
- **Combining or fusing two lighter nuclei into a stable and heavier nucleus. It gives very large amount energy.**
- **This process does not emit any kind of radioactive rays.**
- **This process does not give a rise to chain reaction**

S.no	Fission	Fusion
1.	It is the process of splitting a heavy nucleus with some projectiles into two or more light fragments by liberation of large amount of energy	It is a process of fusing two light nuclei into single nucleus with the liberation of large amount of heat.
2.	This process results the emission of radioactive rays.	Does not emit any kind of radioactive rays.
3.	This process gives a rise to chain reaction	Does not gives a rise to chain reaction
4	Nuclear fission can be controlled conditions.	Nuclear fusion cannot be controlled conditions..

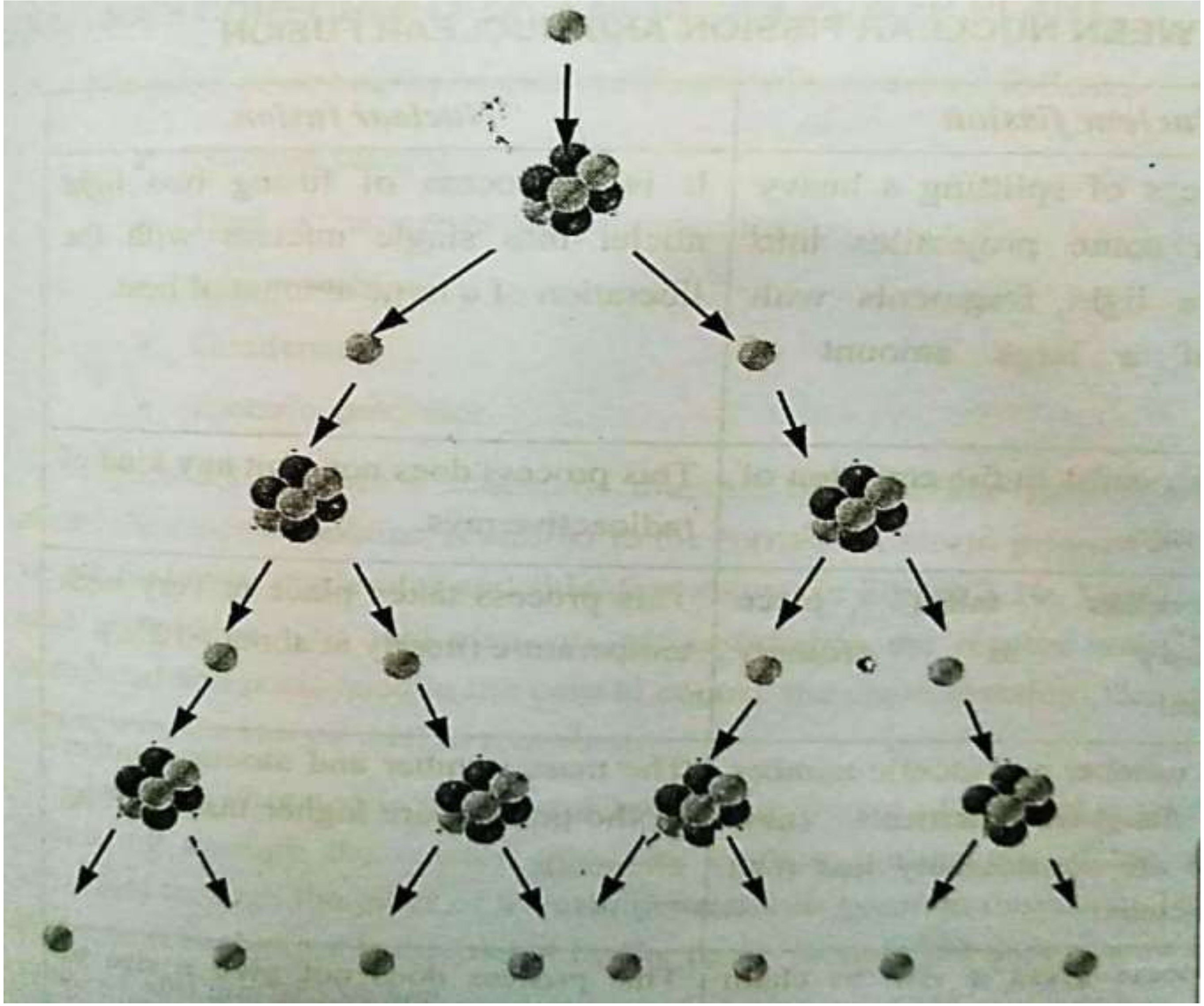
Chain Reaction



Controlled chain reaction



Un controlled chain reaction

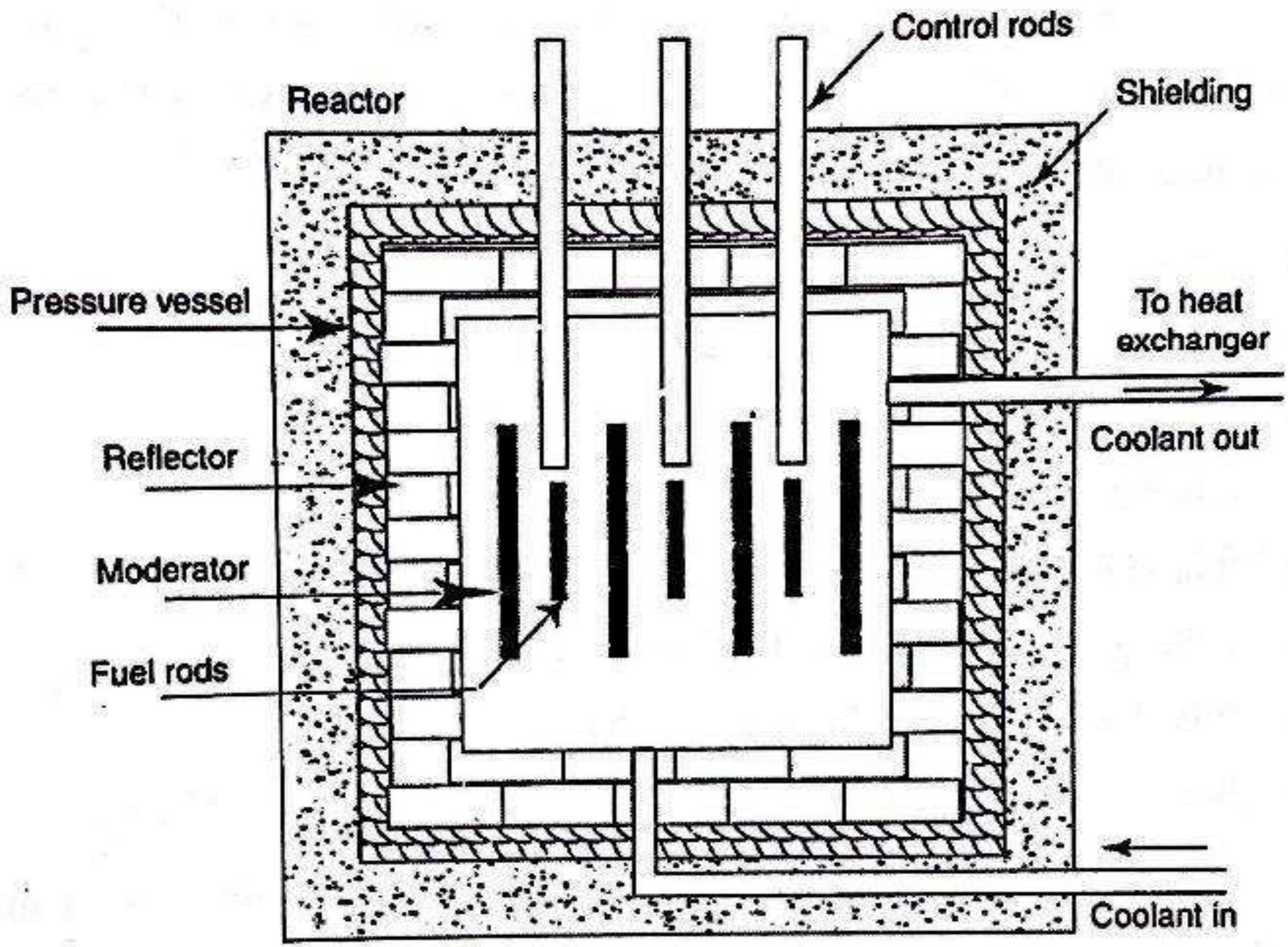


- **A chain reaction is that process in which the number of neutrons keeps on multiplying rapidly during fission till, whole of the fissionable material is disintegrated**
- **The chain reaction will become self-sustaining only**

Components Of Nuclear Reactor

1) Reactor Core
2) Moderator
3) Control rod
4) Reflector
5) Cooling System
6) Reactor Vessel
7) Biological Shielding

Components Of Nuclear Reactor



Reactor Core

- **Nuclear fission takes place in the reactor only.**
- **Nuclear fission produces large quantity of heat.**
- **The shape approximately a circular cylinder(0.5m – 15m)**

Control Rods:

- **They are used to control the chain reaction**
- **They are absorbers of neutrons.**
- **The commonly used control rods are made up of cadmium or boron.**

Moderator:

- **Moderators are used to slow down the fast neutrons.**
- **It reduces 2 MeV to an average velocity of 0.025 eV.**
- **H_2O (or) D_2O are used as moderators.**

Fuel Rods:

- **The fuel rods hold nuclear fuel in a nuclear power plant.**

Reflectors:

- **To prevent the leakage of neutrons to large extent.**
- **In Pressurised Heavy Water Reactor (PHWR), the moderator itself acts as reflectors.**
- **Graphite or beryllium**

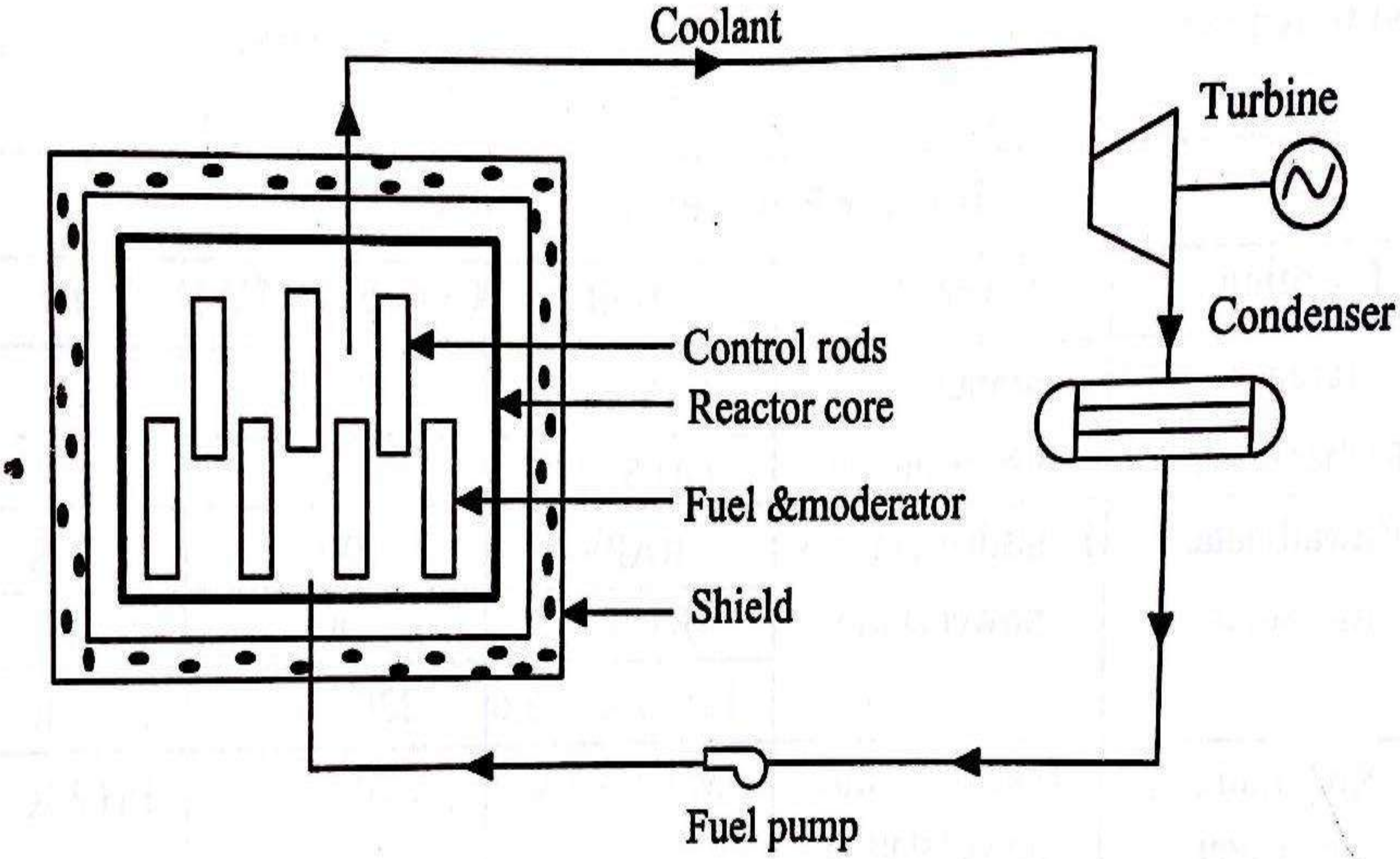
Shielding:

- **To protect from harmful radiations the reactor is surrounded by a concrete wall of thickness about 2 to 2.5 m.**

Types of Reactor

1) Boiling Water Reactor(BWR)
2) Pressurised Water Reactor(PWR)
3) Fast Breeder Reactor(FBR)
4) Gas Cooled Reactor
5) Liquid Metal Cooled Reactor
6) CANDU Type Reactor

BOILING WATER REACTOR(BWR)



Fuel : **Enriched Uranium**

Moderator : **Water**

Coolant : **Water**

Advantages:

1)High exchanger circuit is eliminated
2)Higher thermal efficiency

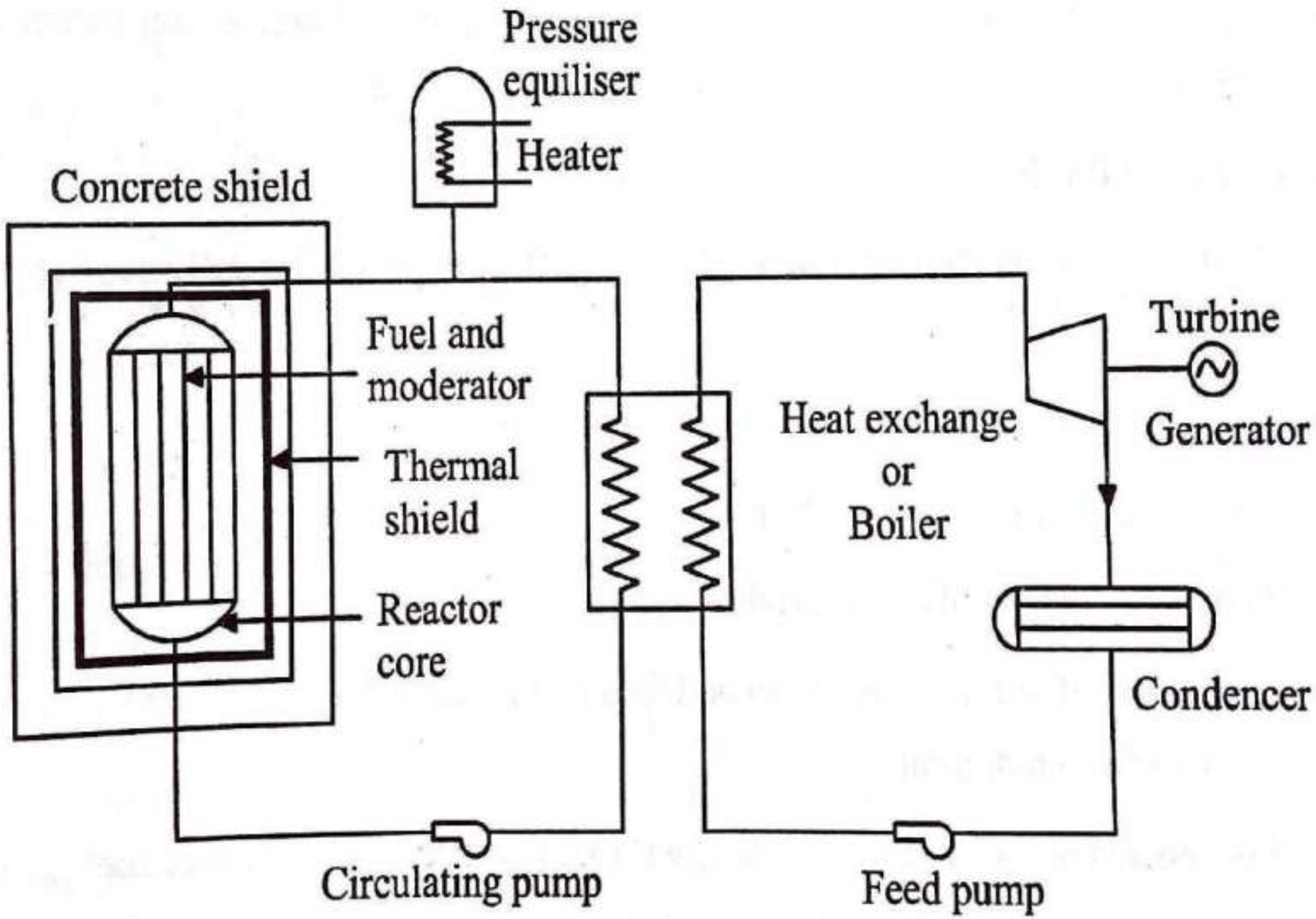
3)Pressure inside the vessel is considerably smaller than PWR.

4)The reactor is more stable than the PWR

Disadvantages:

- **BWR cannot meet sudden increase in power demand**
- **Steam leaving the reactor is radioactive**
- **The power density of the reactor is low**
- **Size of the vessel is considerably large**
- **Possibility of radioactive contamination is present**

PRESSURIZED WATER REACTOR(PWR)



Fuel	**: Both Natural &Enriched Uranium**
Moderator	**: Water**
Coolant	**: Water**

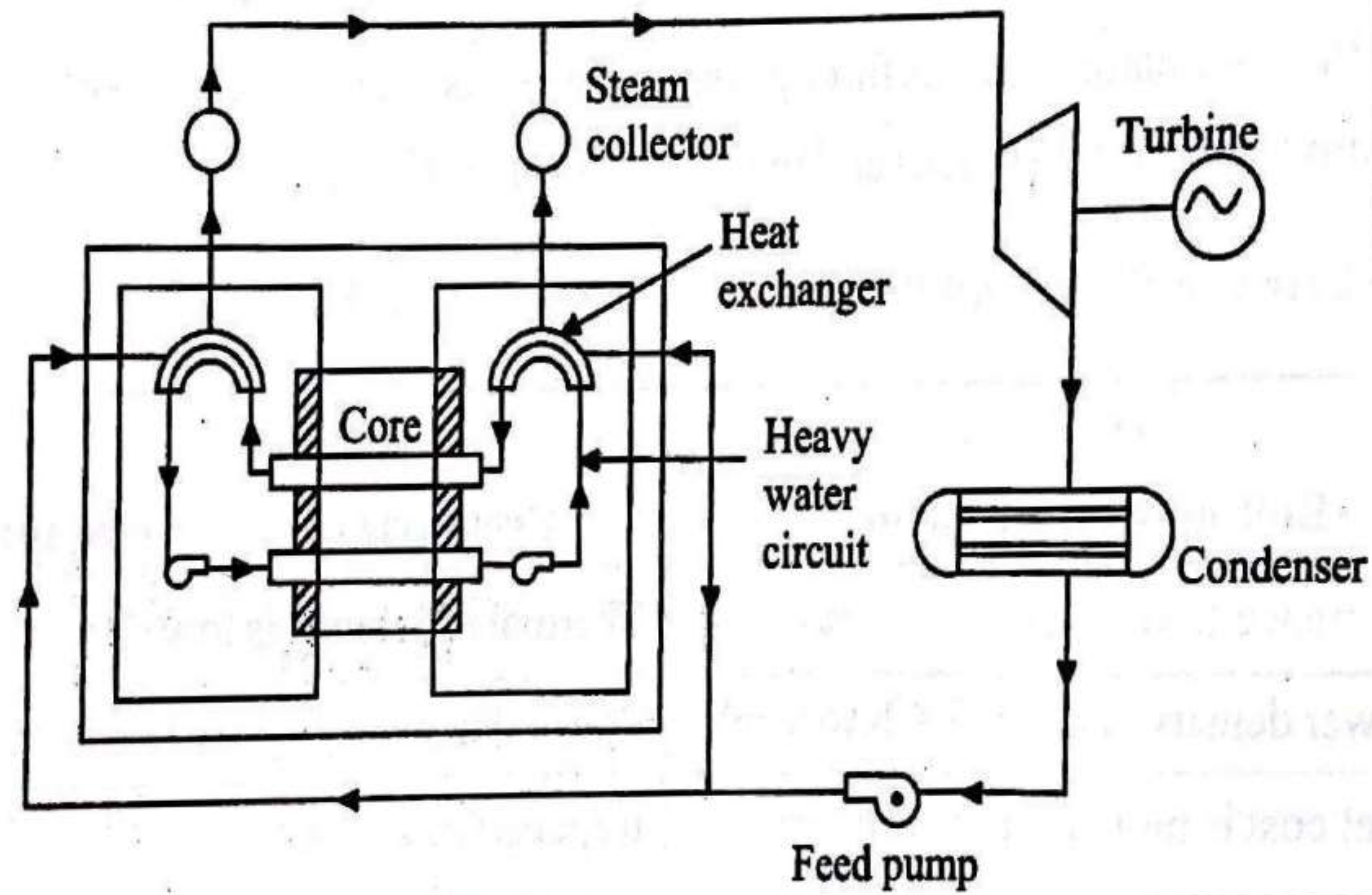
Advantages:

- Water is used as coolant, which is readily available with low cost
- The reactor is compact and high power density
- Only low number of control rods are required
- Inspection of turbine, condenser and feed pump is very easy as it is free from radiation
- Fuel cost is reduced as more energy is extracted per unit weight of fuel

Disadvantages:

- High pressure in the primary circuit requires strong pressure vessel and so high capital cost.
- Due to low pressure in the secondary circuit, the thermodynamic efficiency is low (20%).
- Fuel suffers radiation damage and therefore reprocessing is difficult
- Fuel element fabrication is expensive

CANDU REACTOR



Fuel	**: Natural Uranium**
Moderator	**: D_2O**
Coolant	**: D_2O**

Advantages

1) No control rods required
2) There is no need of enriched fuel
3) The cost of the reactor is less
4) Construction period of the plant is short

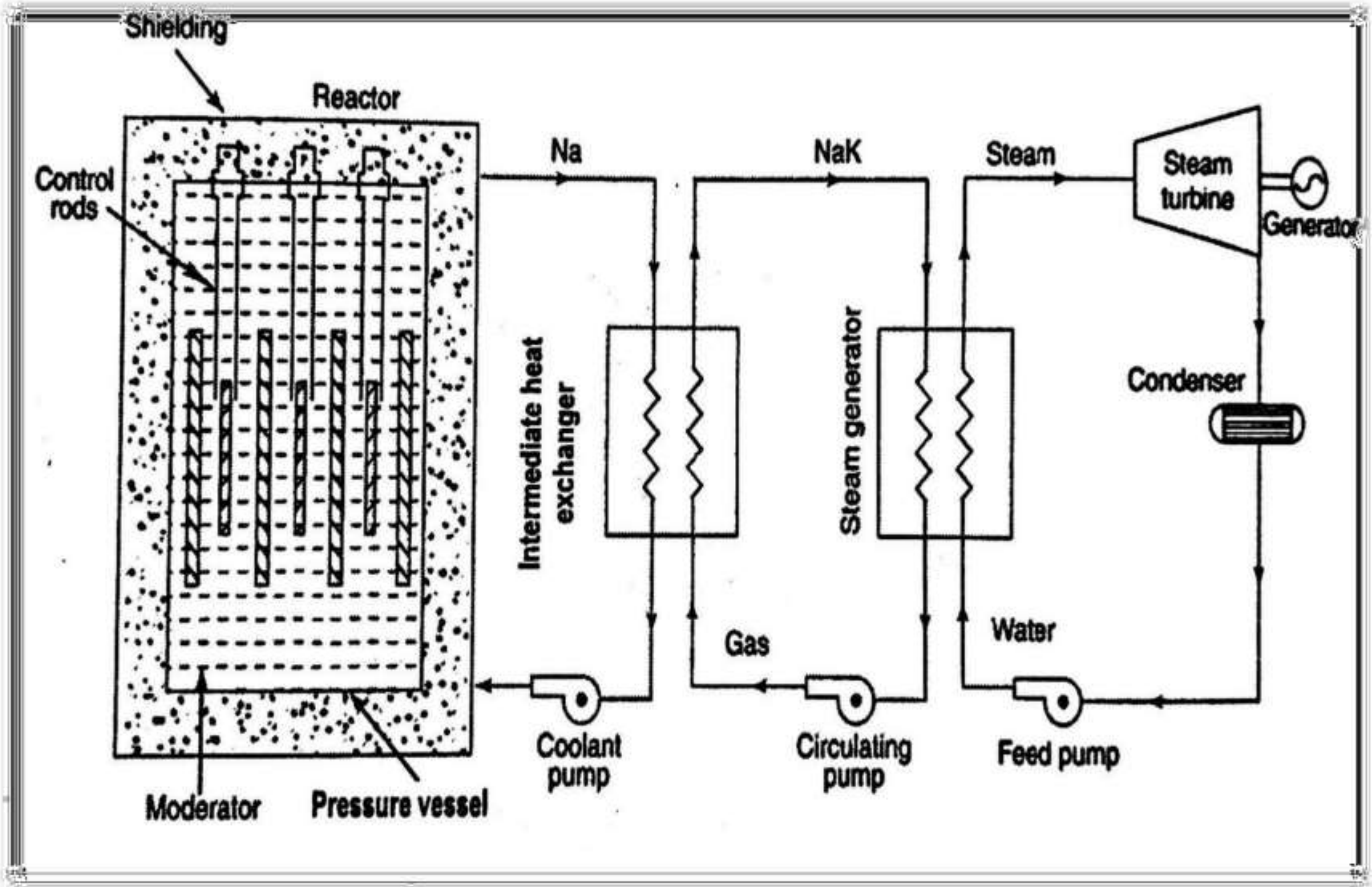
Disadvantages

1) Heavy water is costly
2) Leakage of water is a major problem
3) Power density is low

FAST BREDDING REACTORS

- **An enriched uranium (or) Plutonium(10%) is kept in the casing without moderator**
- **The casing is surrounded by blanket of depleted fertile uranium**
- **The thermal efficiency of the fast reactors is in the range of 40% - 45%**

SODIUM COOLED FAST BREEDER REACTOR (SFBR)



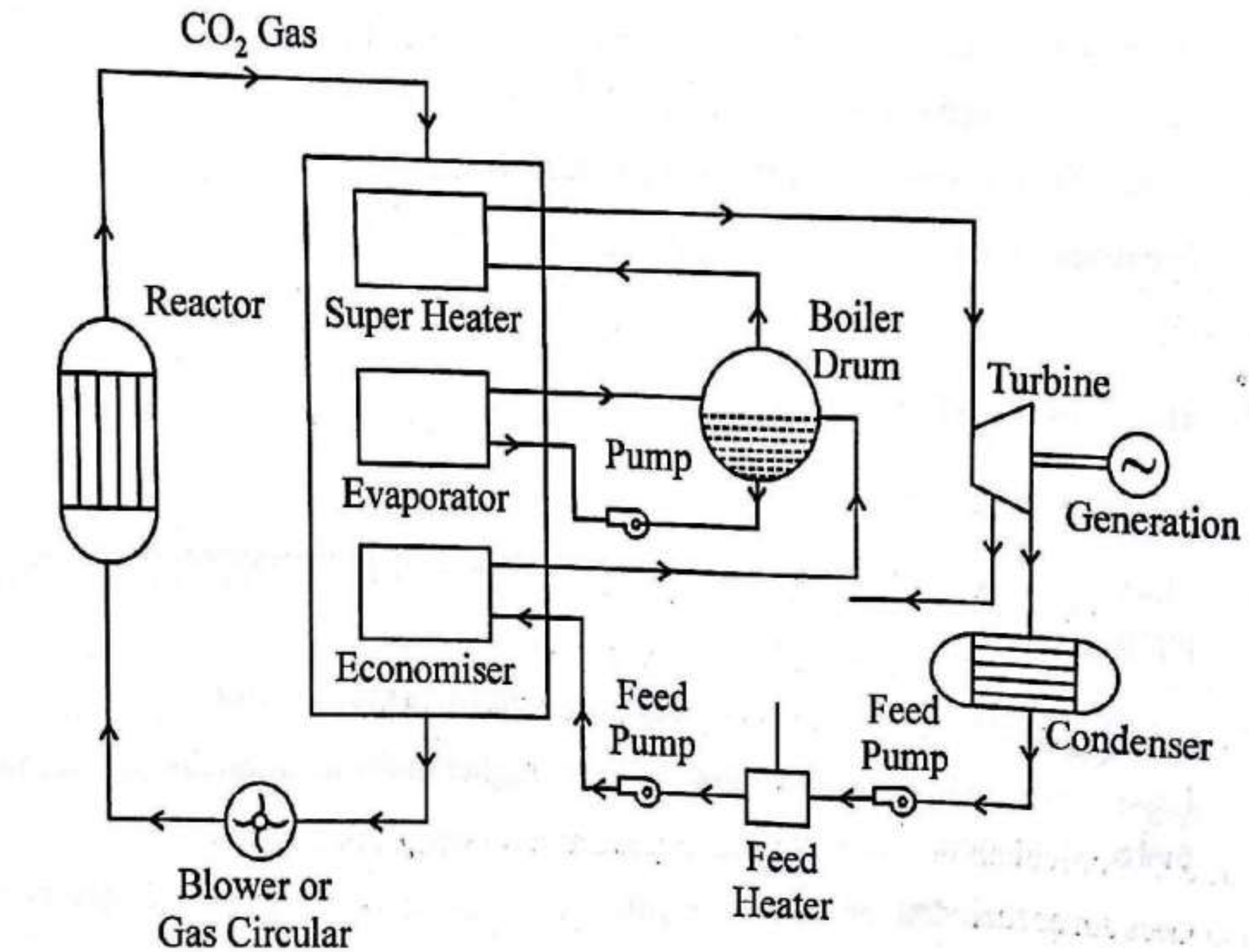
ADVATAGES OF SFBR

- **No moderator is required**
- **High breeding is possible**
- **It gives more power density**
- **High efficiency in the order of 40% can be obtained**
- **It ensures a better fuel utilization**

DISADVATAGES OF SFBR

- **It requires highly enriched fuel**
- **Handling of sodium is a major problem. Because it becomes hot and radioactive**
- **Special coolants are required**
- **Safety must be provided against melt-down**

GAS COOLED REACTORS



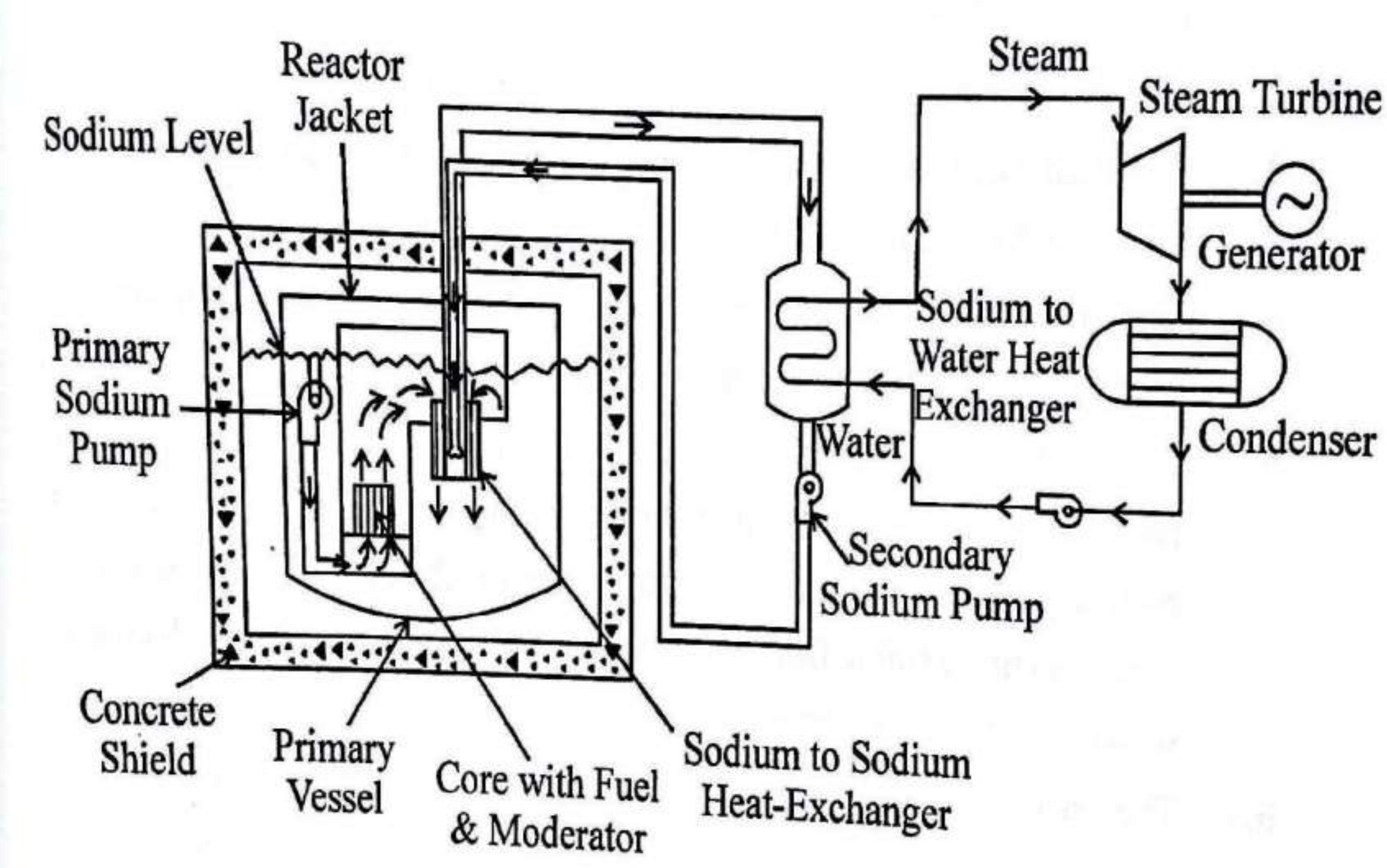
ADVANTAGES OF GAS COOLEDREACTOR

- **This is simpler fuel processing**
- **CO_2 as coolant completely eliminates the possibility of explosion in reactor**
- **There is no corrosion problem**

DISADVANTAGES OF GAS COOLED REACTOR

- **The loading of fuel is more elaborate and costly**
- **Power density is very low due to low heat transfer co-efficient**
- **The leakage of gas is a major problem if helium is used instead of CO2**

LIQUID METAL COOLED REACTOR



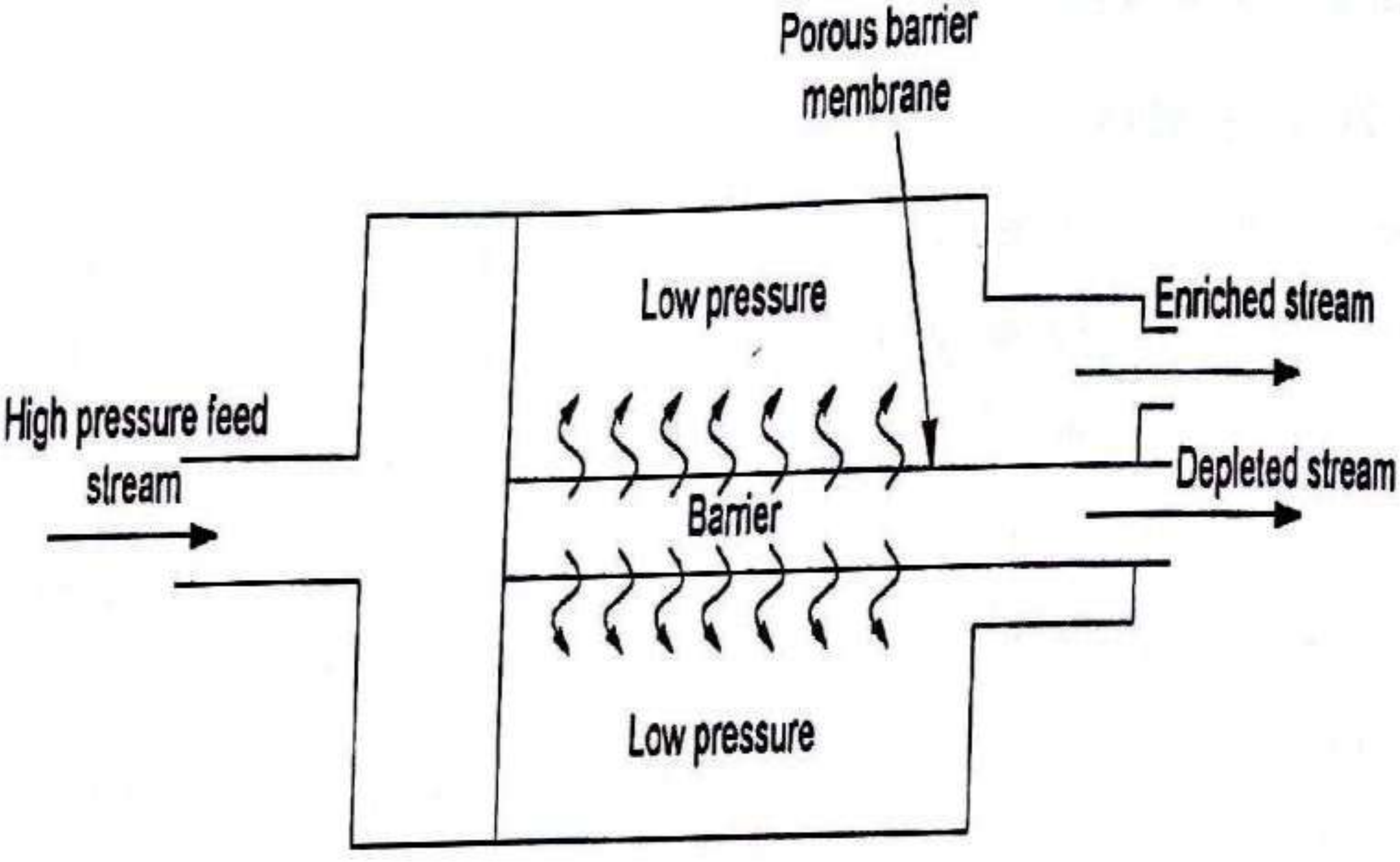
URANIUM ENRICHMENT

- Enriched uranium is a type of uranium in which the percent composition of uranium-235 has been increased through the process of isotope separation.
- Natural uranium is 99.284% ^{238}U isotope, with ^{235}U only constituting about 0.711% of its mass. ^{235}U is the only nuclide existing in nature (in any appreciable amount) that is fissile with thermal neutrons.

ENRICHMENT METHOD:

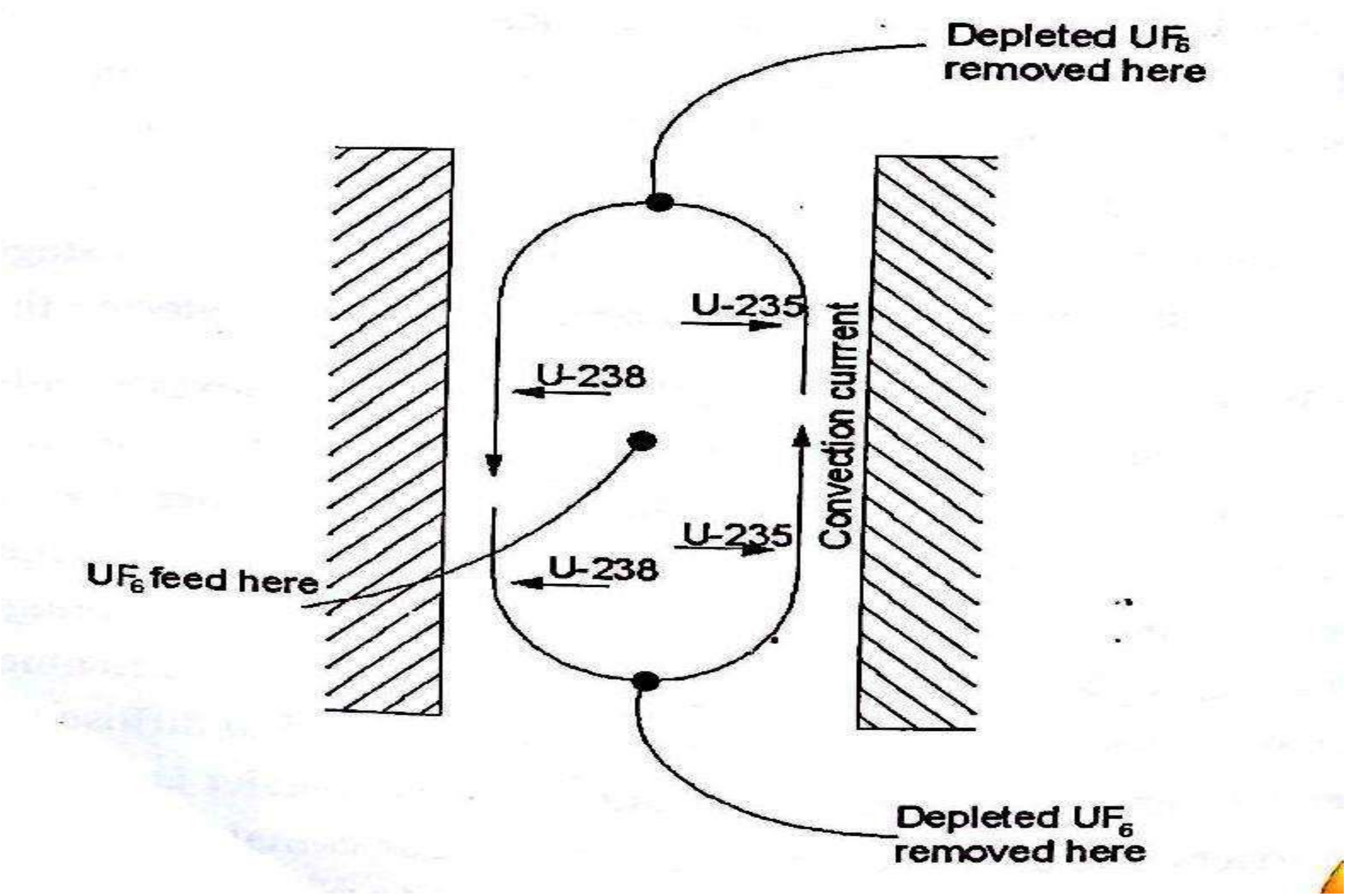
1)Gas centrifuge 2)Gaseous diffusion 3) Thermal diffusion

1) Gaseous diffusion



- **Gaseous diffusion is a technology used to produce enriched uranium by forcing gaseous uranium hexafluoride (hex) through semi-permeable membranes.**
- **This produces a slight separation between the molecules containing ^{235}U and ^{238}U.**

2. Thermal diffusion



- **Thermal diffusion utilizes the transfer of heat across a thin liquid or gas to accomplish isotope separation.**
- **The process exploits the fact that the lighter ^{235}U gas molecules will diffuse toward a hot surface, and the heavier ^{238}U gas molecules will diffuse toward a cold surface.**

Selection of Nuclear Power Plant

1. Proximity to load center
2. Population distribution
3. Land use
4. Meteorology
5. Geology
6. Hydrology
7. Seismology.

Safety Measures

- Proper design, plant layout and adequate shielding:
- Limits of air contamination levels in different zones of the plant:
- Source control by proper selection of materials/components:
- To shut down operating reactors
- To cool down reactors so as to remove heat from nuclear fuel
- To contain radioactive materials

Safety in Modern

Figure 3.21 shows the *defence-in-depth* strategy of design of modern nuclear power plants. Current plants may have some or all of these defences. The defences vary depending on the type of plant, nation constructing them, use (civilian, military, naval vessels) and age.

1. First layer of defence is the inert, ceramic quality of the uranium oxide itself.
2. Second layer is the air tight zirconium alloy of the fuel rod.
3. Third layer is the reactor pressure vessel made of steel more than a dozen centimeters thick.
4. Fourth layer is the pressure resistant and air tight containment building.
5. Fifth layer is the reactor building or newer power plants in a second outer containment building.

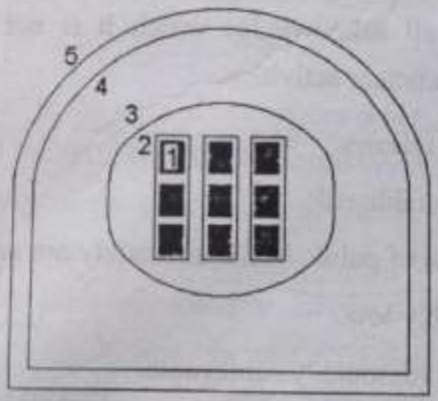


Figure 3.21 Defence-in-depth safety system in modern nuclear plant

UNIT - IV

POWER FROM RENEWABLE ENERGY

About Renewable Energy,

- **Hydro Power Energy**
- **Wind Energy**
- **Tidal Energy**
- **Geo Thermal Energy**
- **Bio-gas Energy**
- **Solar Energy**

Hydro Power Energy

Hydropower is a commercial source of energy which supplies 30% of the total electricity of the world.

Potential Energy → **Kinetic Energy**

↓

Mechanical Energy

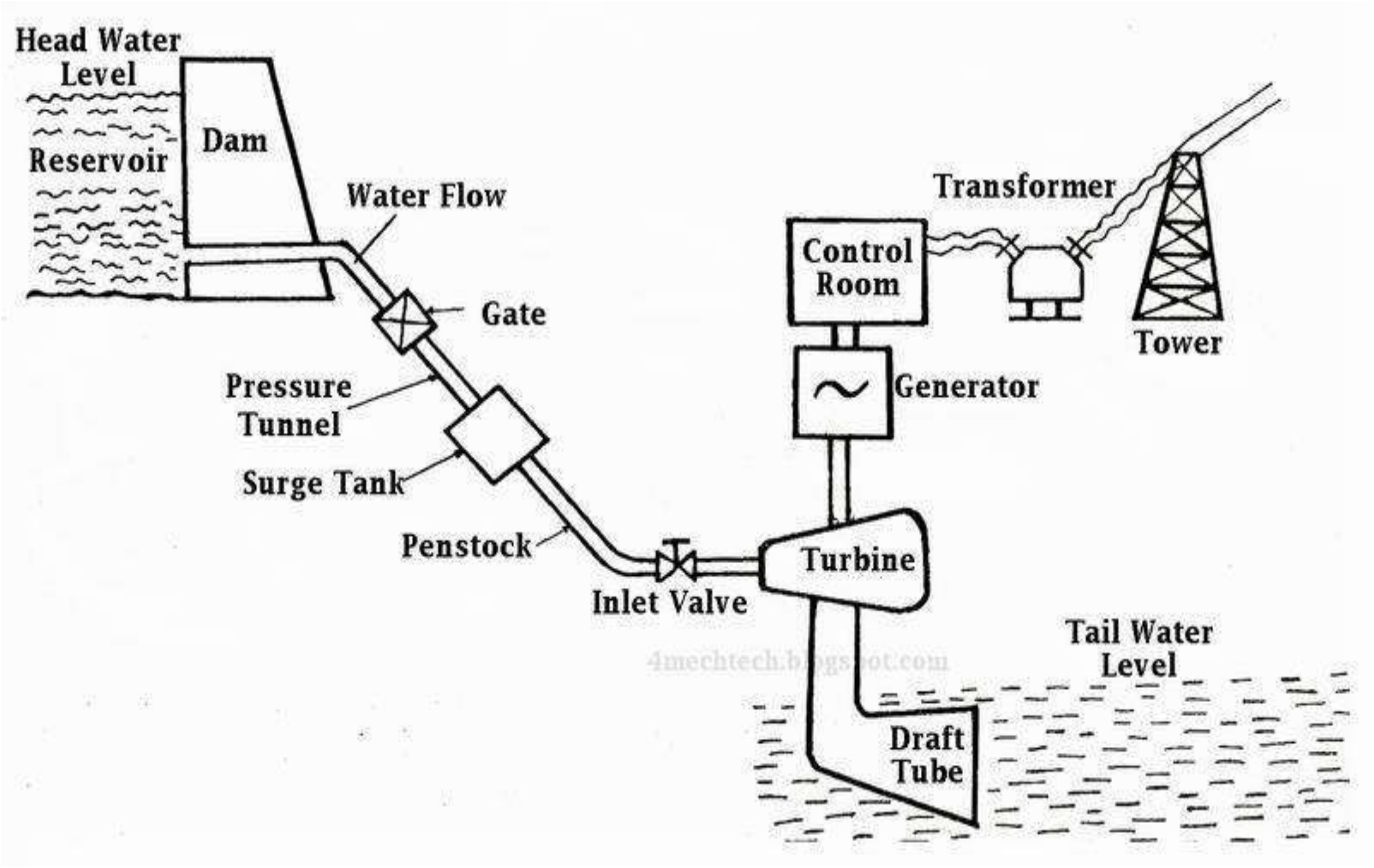
↓

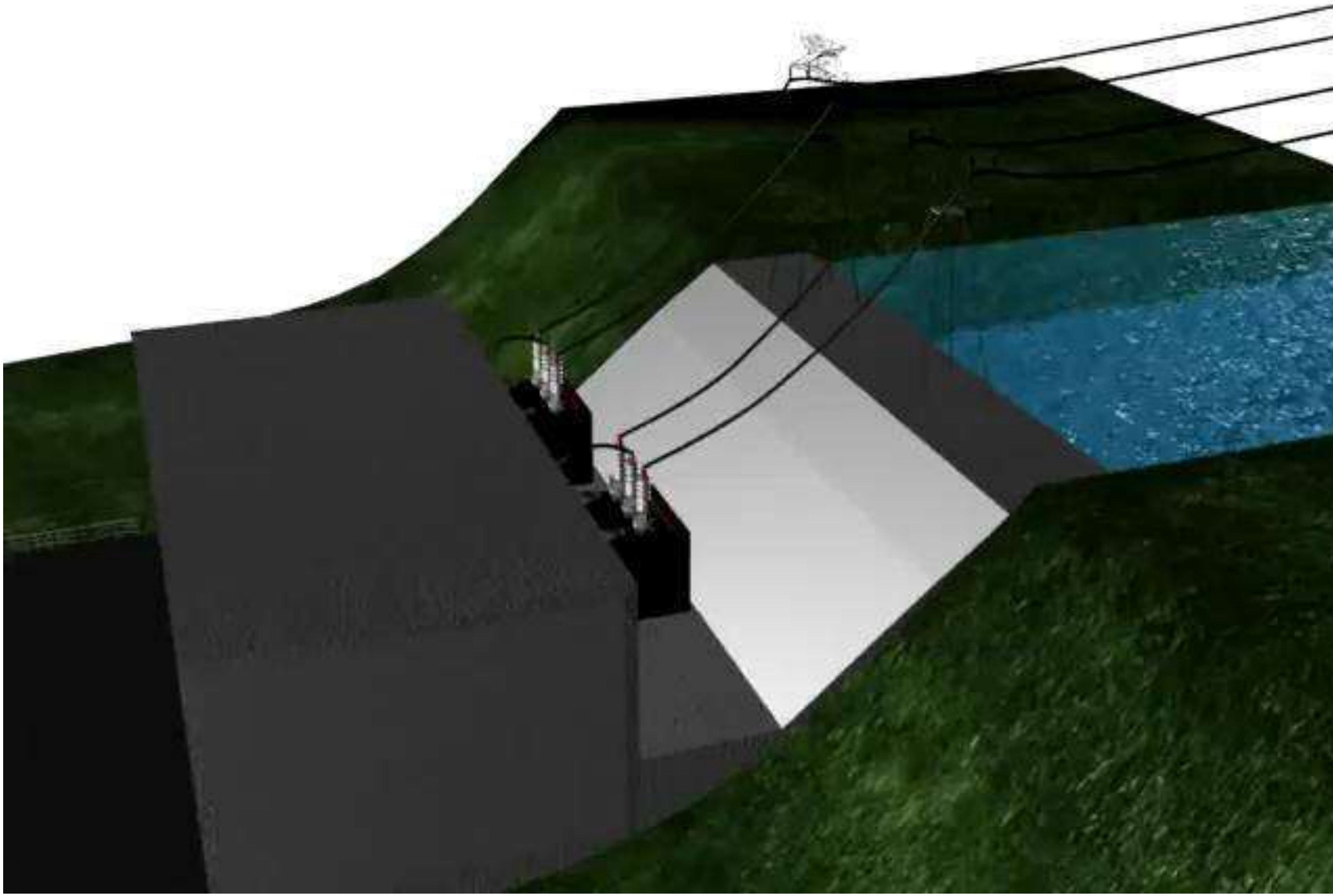
Electrical Energy

Components of Hydro Power Plant

- **Reservoir**
- **Dam**
- **Spillways**
- **Trash Rack**
- **Fore bay**
- **Water Tunnel**
- **Penstock**
- **Surge tanks**
- **Water turbine**
- **Draft tubes**
- **Tailrace**
- **Power house and equipment**

Layout Of Hydro Power Plant





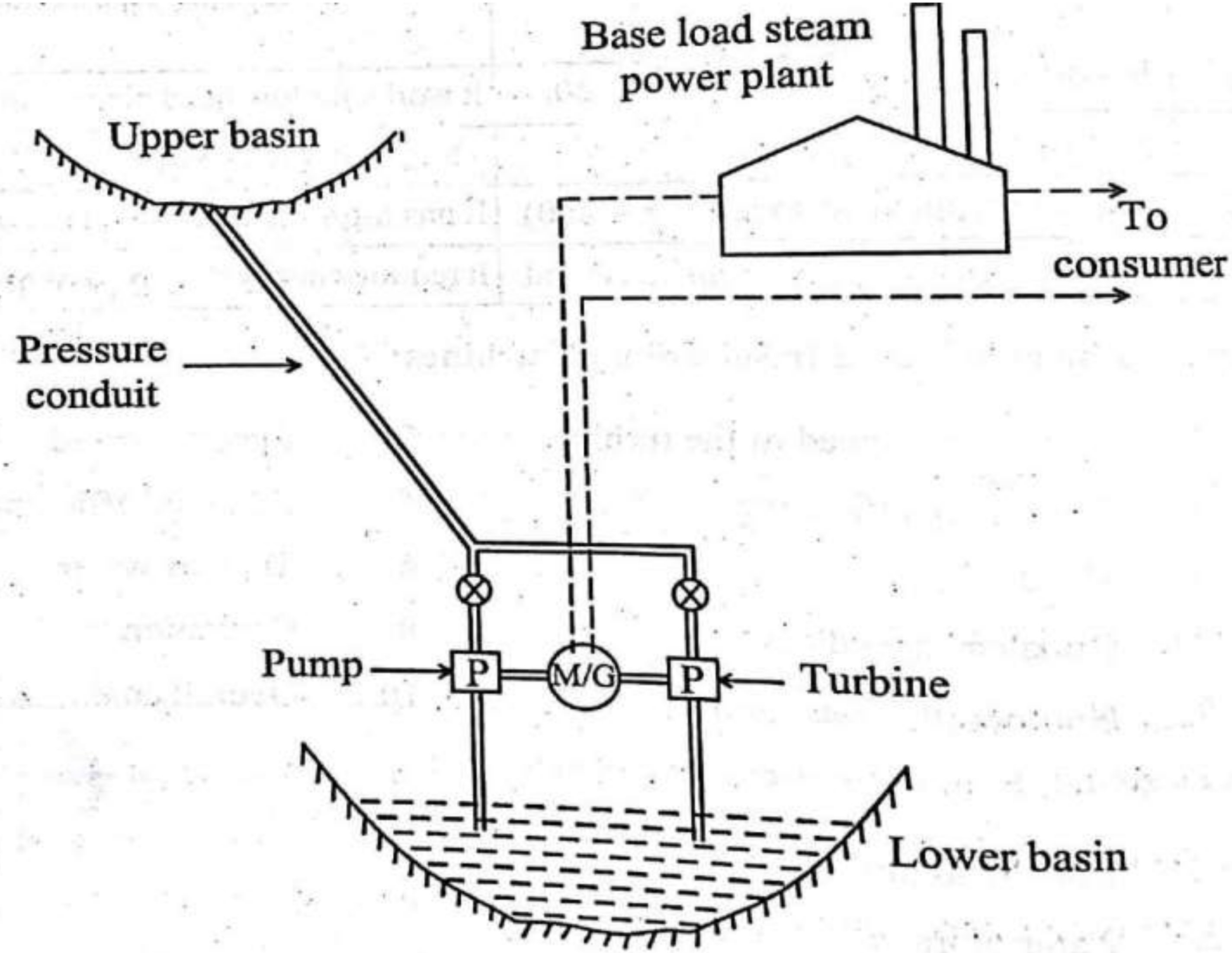
Advantages

- **They are highly reliable**
- **Maintenance and operation & Running cost are very low**
- **No fuel charges & No stand by losses & No ash handling problem**
- **Number of operation required is small**
- **Along with power generation, these plants are also used for flood control and irrigation**

Disadvantages

- The initial cost of the plant is very high
- The time taken far erection of such plants is considerably longer
- It is purely dependent on rainfall. If the rainfall is not adequate in a year, then this plant cannot be utilized

Pumped Storage Power plant



Site Selection For Hydro Power Plant

- **Water availability**
- **Water storage**
- **Water head**
- **Various Geological investigations**
- **Environmental aspects**
- **Consideration of water pollution effects**

Water Turbines

Kinetic Energy → Mechanical Energy

Classification:

1. The action of water flowing

a) Impulse turbine

→ Pelton Wheel

b) Reaction turbine

→ Francis & Kaplan turbine

2. The direction of flow water:

a) Tangential flow

b) Radial flow

c) Axial flow

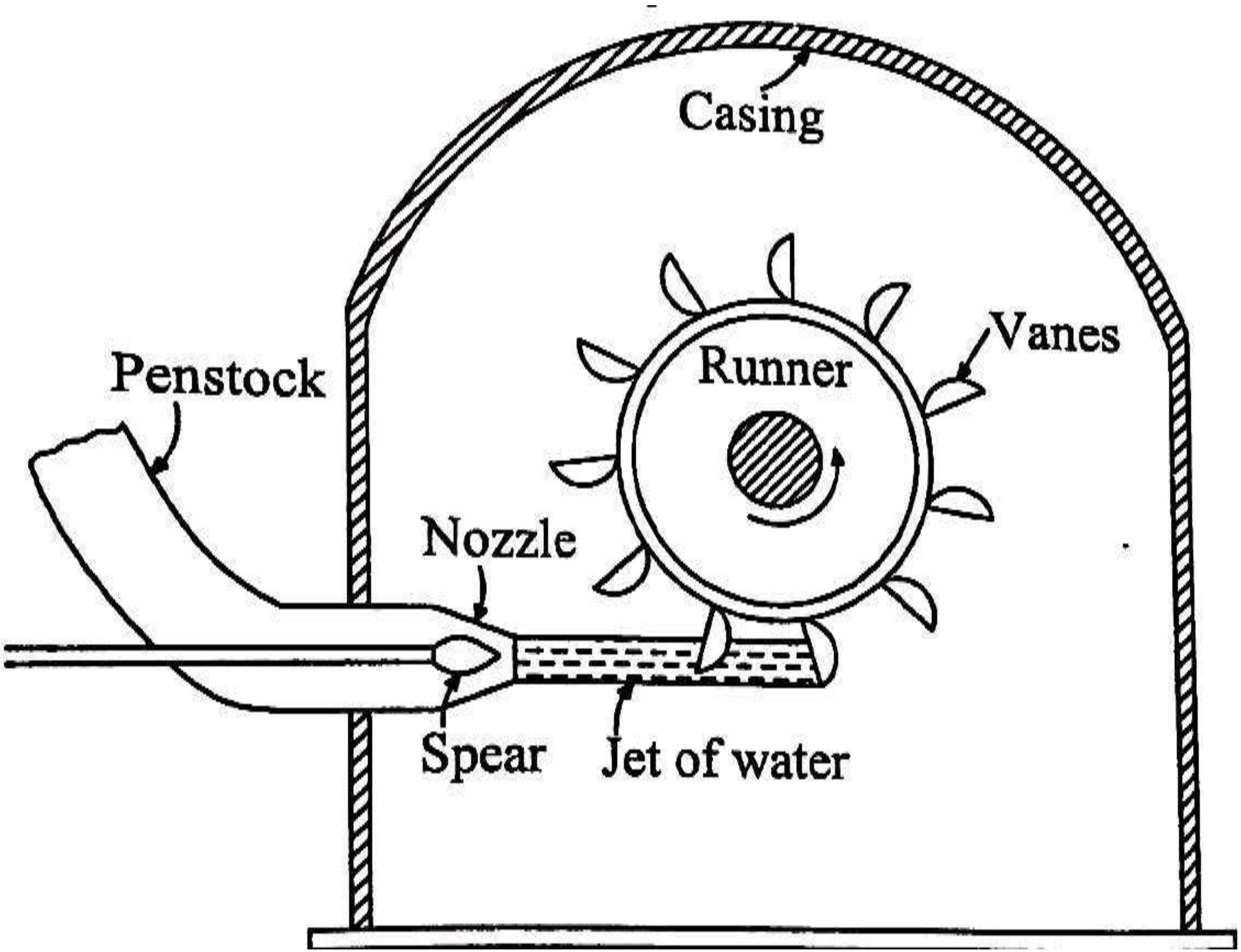
3. The head and quantity of water:

a) High head (above 250m)

b) Medium head (60m – 250m)

c) Low head (less than 60m)

Pelton Wheel Turbine



Components

- Runner
- Nozzle
- Spear
- Brake jet
- Bucket
- Casing
- Penstock

Advantages

- It is a tangential flow impulse turbine
- High head turbine (more then250m).
- It's have more hydraulic efficiency.
- It's involves less maintenance work

Disadvantages

- **Low specific speed**
- **Water is admitted only in the form of jet**
- **The runner consists of a circular disc with a number of buckets evenly spaced around its periphery**

WIND ENERGY

WIND ENERGY → **MECHANICAL ENERGY**

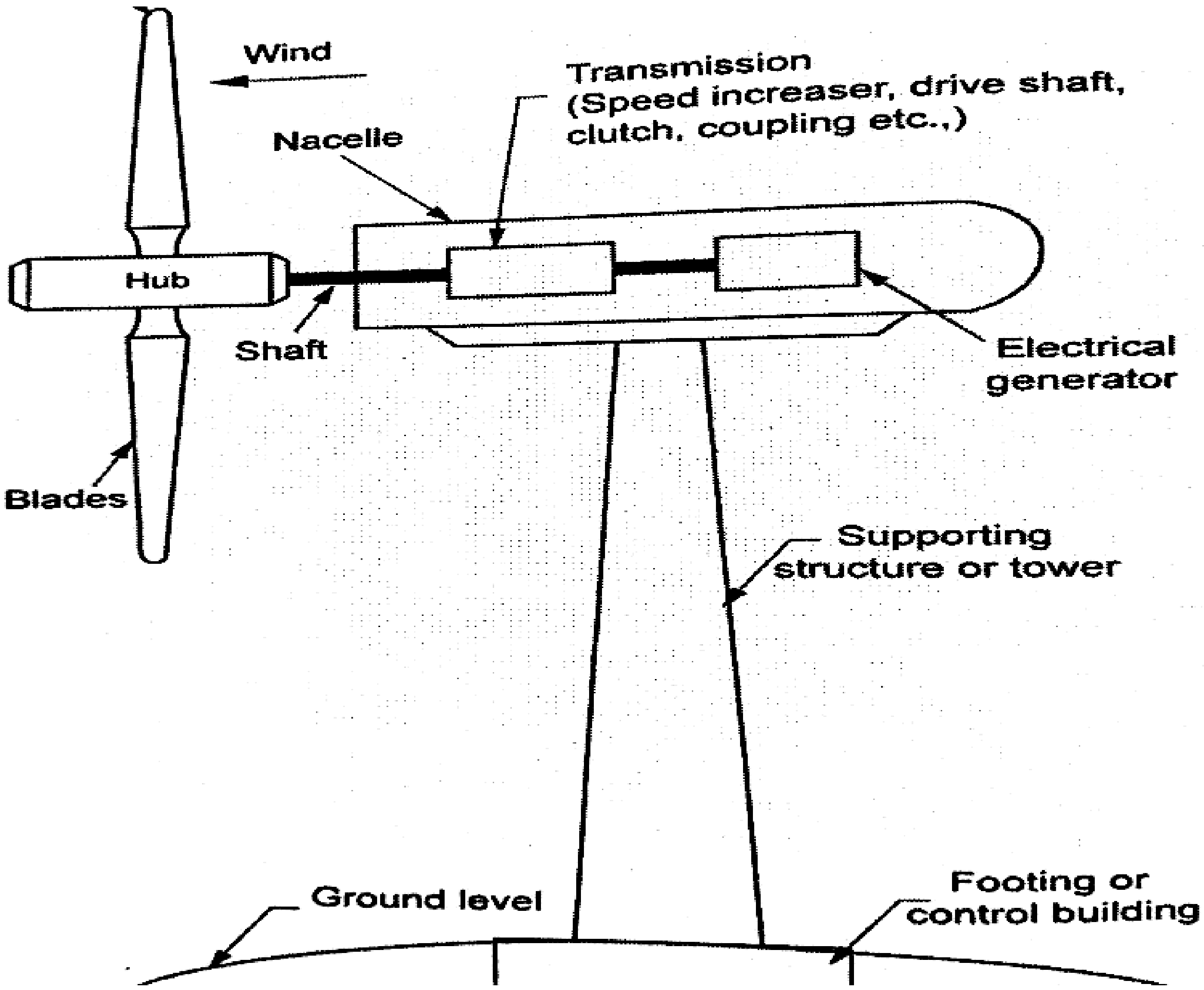
↓

ELECTRICAL ENERGY

Basic features:

1. **Drag is in the direction of airflow**
2. **Lift in perpendicular to the direction of airflow**

Construction Of Wind Mill (or) Turbine



Components

1. Wind Turbine
    a) Nacelle
    b) Rotor
    c) Hub and Shaft
    d) Anemometer
2. Transmission system
3. Electric generator
4. Yaw control system
5. Storage
6. Energy converter
7. Towers

Advantages

1. Clean Energy
2. Free from pollution
3. Place ability
4. Decentralised
5. Domestic
6. Remote area supply

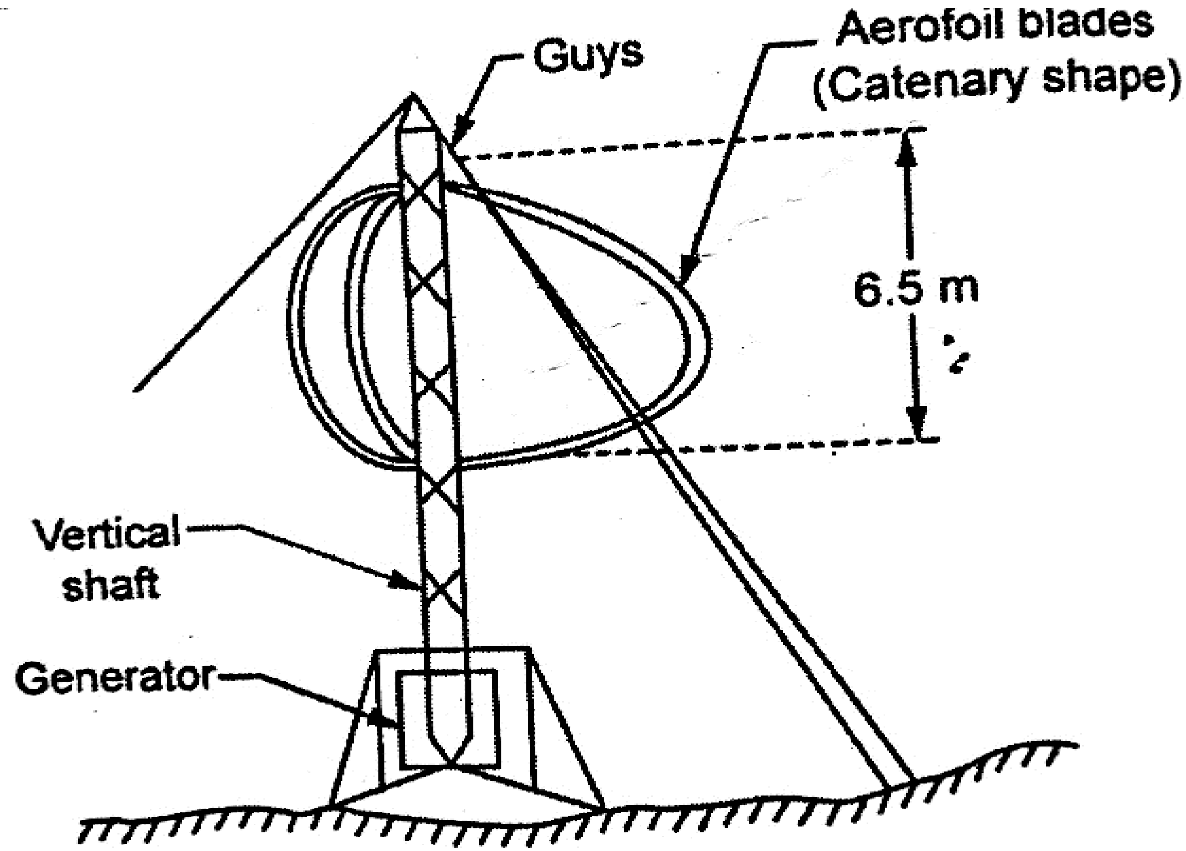
Disadvantages

1. **Reliability**
2. **Expense**
3. **National security**
4. **Noise**
5. **Wild life**

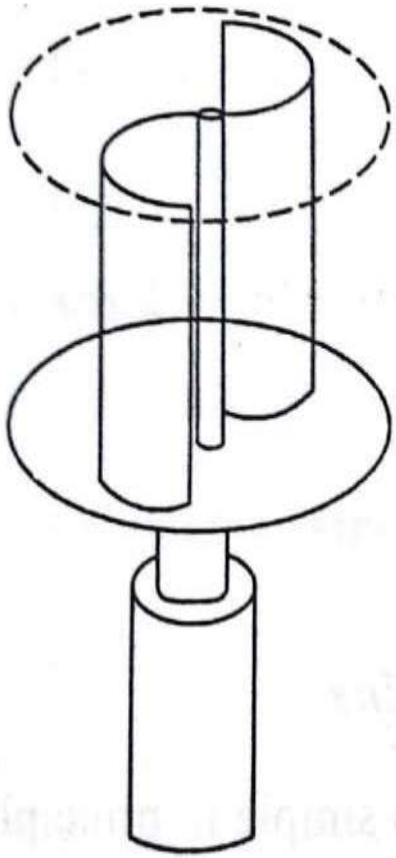
Types Of Wind Turbine

1. Horizontal axis wind turbine

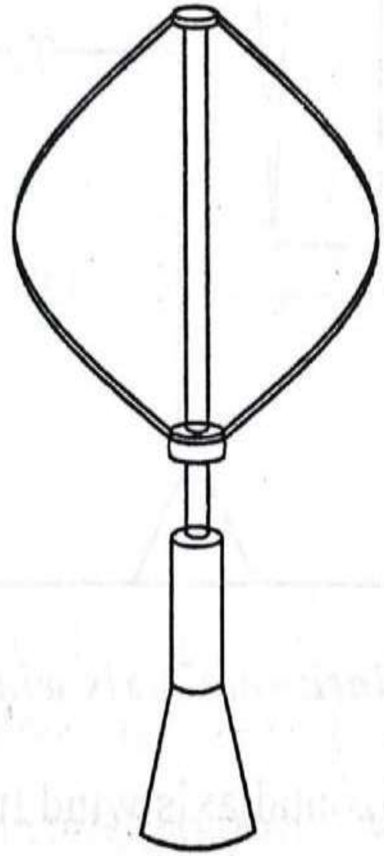
2. Vertical axis wind turbine



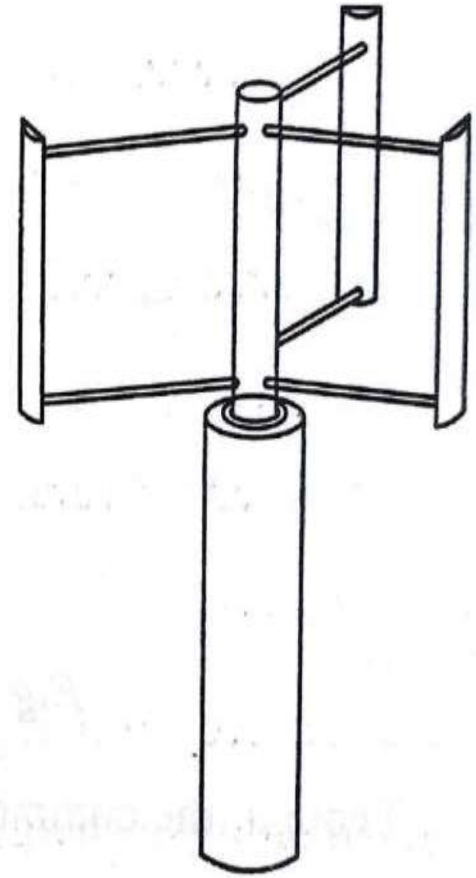
Savonius - rotor



Darrieus-rotor



H-Darrieus-rotor



TIDAL ENERGY

- **The periodic rise and fall of sea water level which are carried by the action of sun and moon on water of the earth is called "Tide"**
- **Nearly 70 % of the tide produces force due to moon and remaining 30% by the sun**

Modes Of Generation Of Tidal

1. Single basin arrangement

One way systems

Two way systems

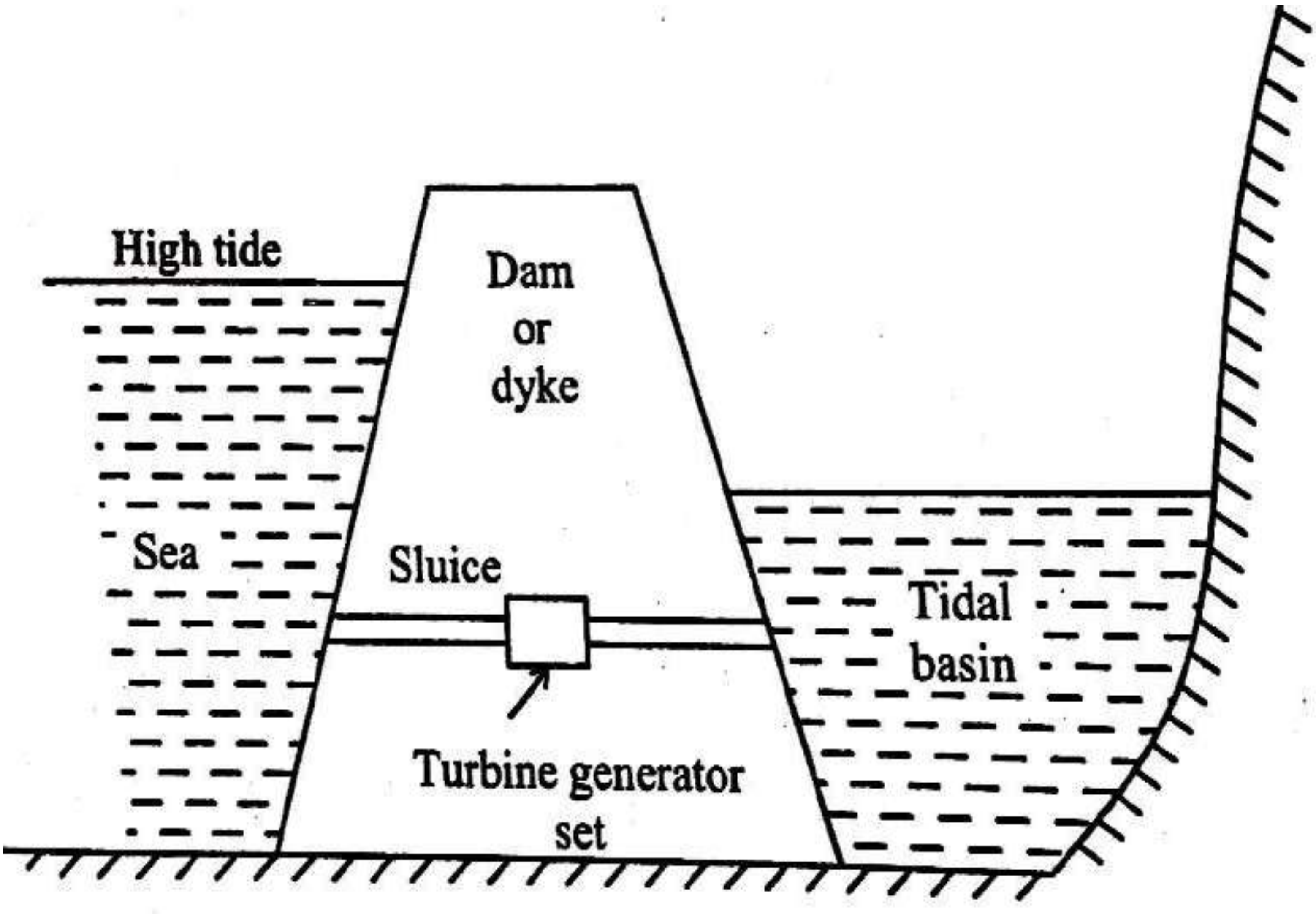
Two way with pump storage

2. Double basin arrangement

Simple double basin

Double basin with pump

Single Basin Arrangement



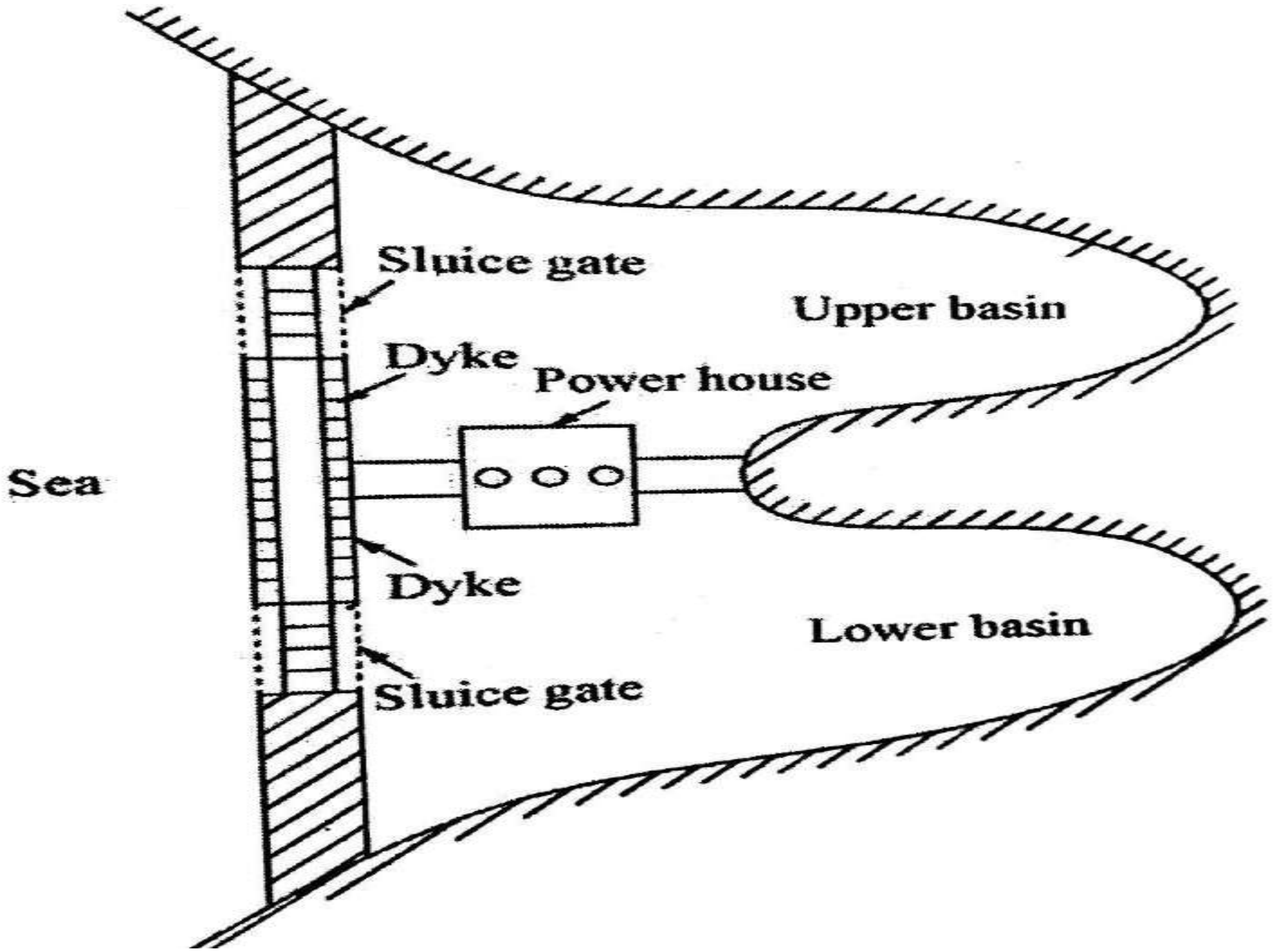
Advantages:

- A single basin cannot generate power continuously, through pumped storage may be used still fluctuations occurs continuously

Disadvantages:

- Its construction of the civil work becomes more extensive

Double Basin Arrangement



Advantages:

- A double basin scheme can provide power continuously or on demand

Disadvantages:

- Its construction of the civil work becomes more extensive

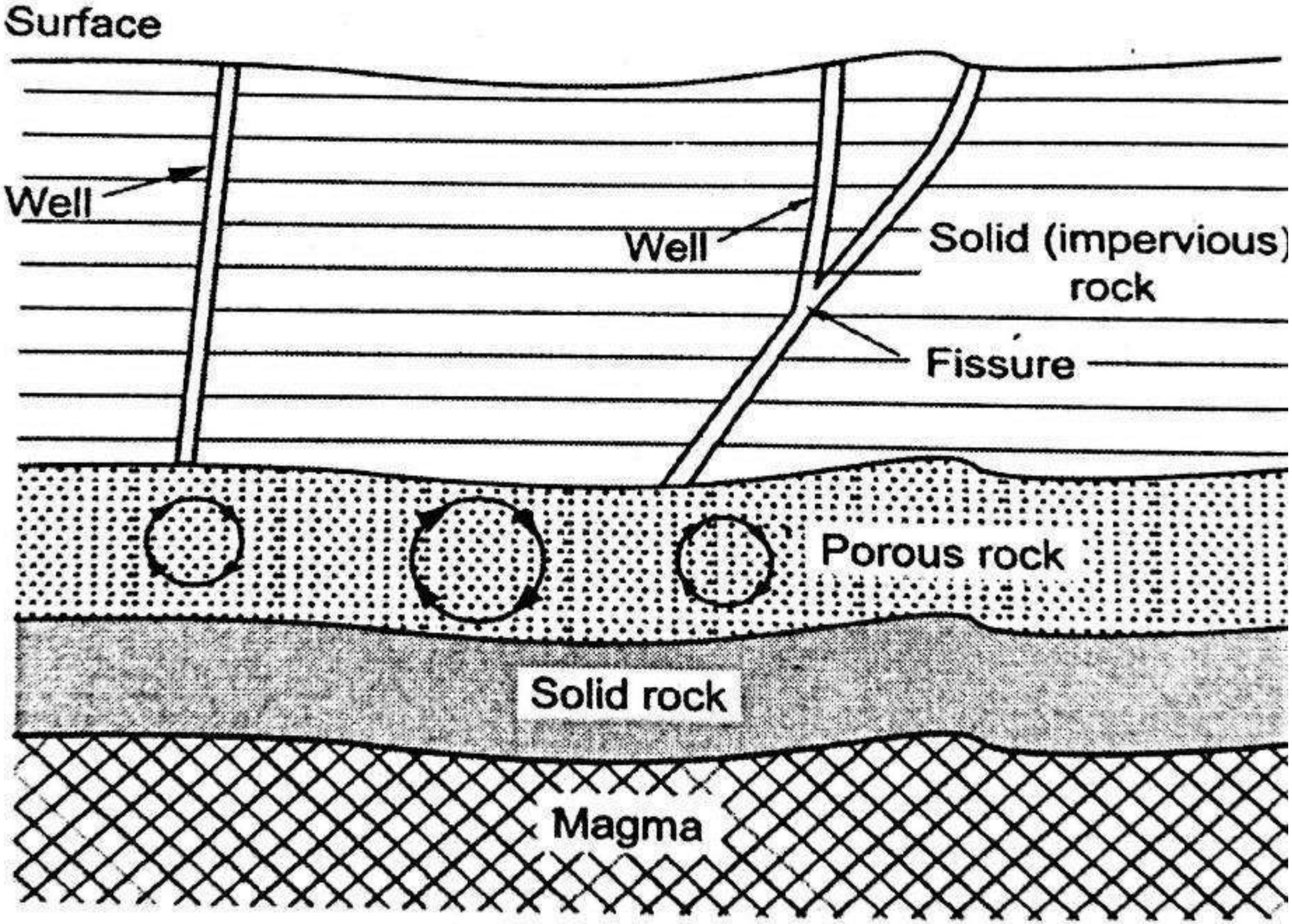
GEO THERMAL ENERGY

THERMAL ENERGY → MECHANICAL ENERGY

↓

ELECTRICAL ENERGY

- **Thermal(heat) energy in the earth crust**
- **The more readily heat is in the upper crust(10Km) constitutes a potentially useful and inexhaustible source of energy**
- **The average temperature at a depth of 10 Km is 200^0C**
- **The average temperature at a depth of 32 Km is 300^0C**


Surface
Well
Well
Solid (impervious) rock
Fissure
Porous rock
Solid rock
Magma

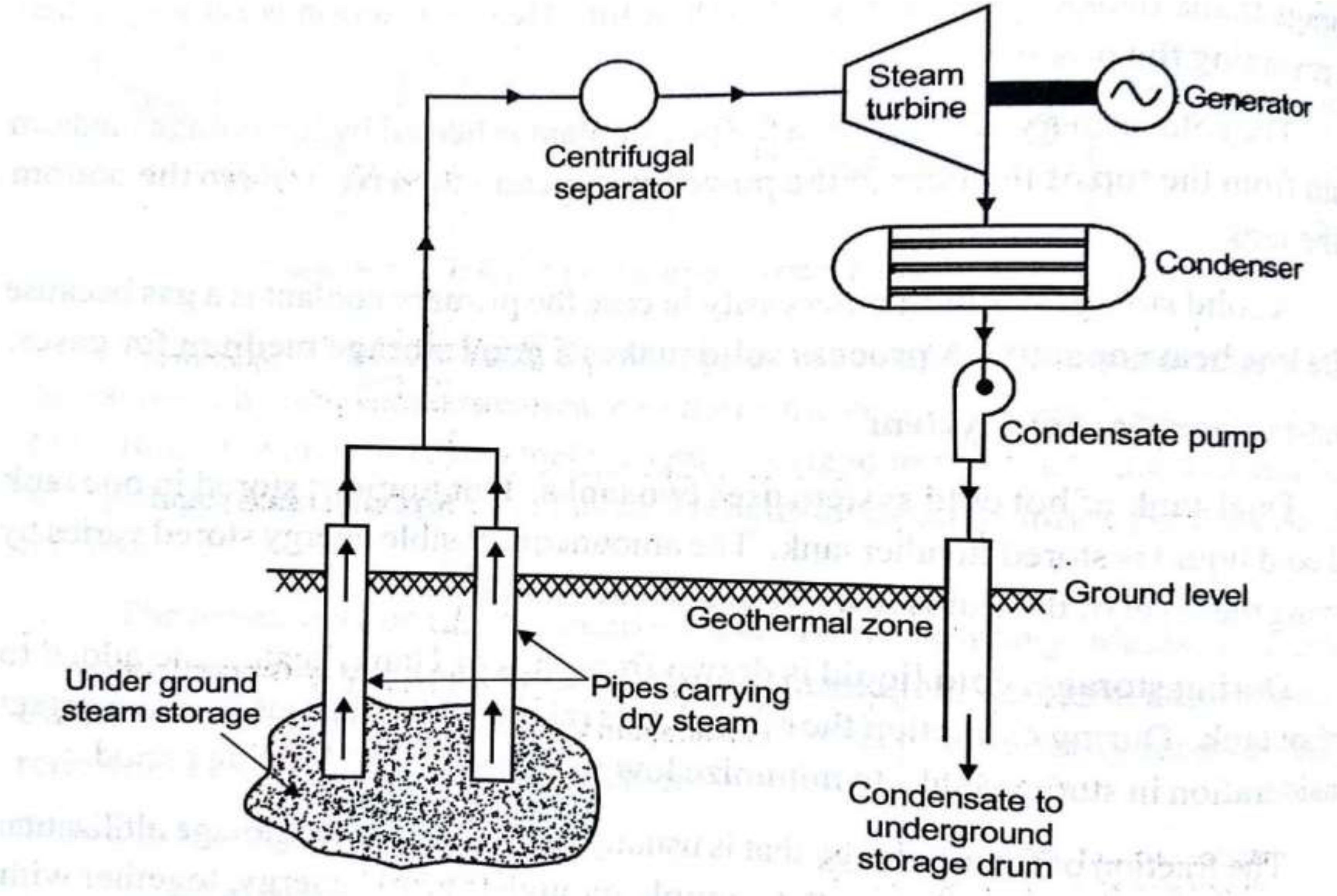
Uses Of Geothermal Energy

1. Space heating
2. Industrial processes
3. Drying
4. Green house
5. Aquaculture
6. Hot water
7. Melting snow

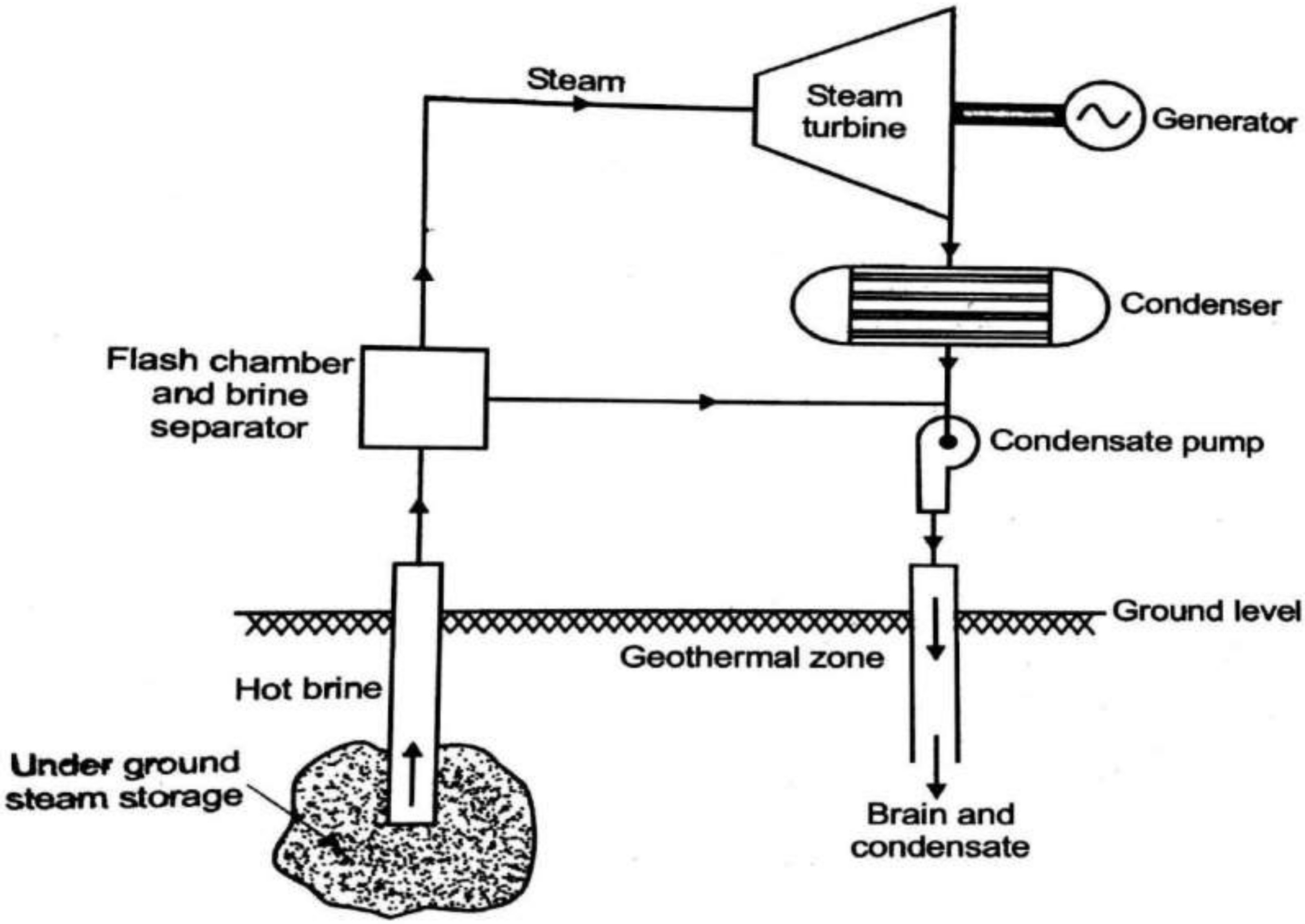
Types Of Geothermal Energy

1. **Dry type (or)Vapour- Dominated**
2. **Wet type (or) Liquid-Dominated**

Dry (Or)vapour-dominated



Wet Type (or)liquid-dominated



Advantages:

1. **Geothermal energy is cheaper**
2. **It is versatile in its use**
3. **It delivers greater amount of net energy**

Disadvantages:

1. **Drilling operation is noisy**
2. **Large areas are needed for exploitation of geothermal energy**
3. **Low overall efficiency**

BIO-GAS POWER PLANT

- The bio-gas plant is used to generate low calorific value biogas ($CH_4 + CO_2$) fuel.
- Biogas plant converts wet biomass into biogas by the process of anaerobic fermentation
- Biogas plants are very popular in India especially in rural areas

COMPOSITION OF BIOGAS

Methane (CH_4)	**= 55 to 60%**
Carbon dioxide (CO_2)	**= 35 to 40%**
Hydrogen (H2)	**= 5%**
H_2S and O_2	**= Traces**

Raw Materials For Biogas

1. **Animal wastes**

   Cow ,cattle and elephant dung,

   Fish waste, Leather waste

2. **Agriculture wastes**

   Crop residue, Sugarcane trash, cotton and textile wastes

3. **Industrial wastes**

   Sugar, paper and tannery etc..

4. **Human waste**

Biofuels

- **Fuel wood**
- **Charcoal**
- **Bio-ethanol**
- **Bio-gas**
- **Producer gas**
- **Vegetable oils**

Important Parts Of A Biogas Plant

- **Digester tank where biomass undergoes decomposition**
- **Inlet tank where biomass is mixed with water**
- **Outlet tank where slurry of the biomass is collected**

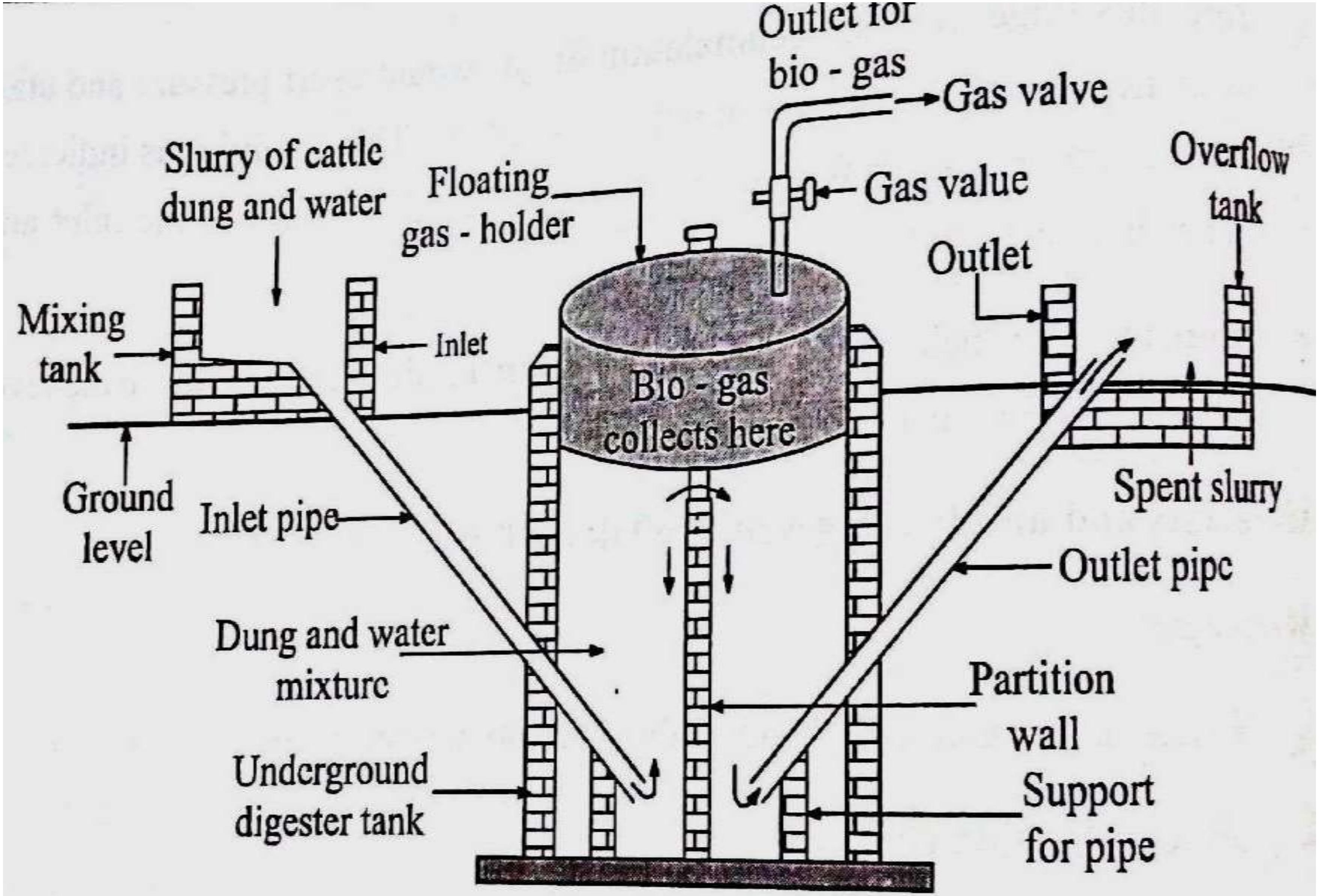
Classification Of Bio Gas Plants

Continuous type bio gas plant

- **Single stage continuous type**
- **Two stage continuous type**

Batch type bio gas plant

- **Fixed dome type**
- **Floating dome type**



Floating gas - holder type bio-gas plant

Advantages:

- **Gas pressure is constant**
- **Scum formation is very less**
- **The danger of explosion is completely eliminated as there is no possibility of mixing of biogas and external air**
- **No gas leakage problem**
- **Volume of gas stored is visible directly**

Disadvantages

- Construction cost is high
- Steel parts are liable to corrosion
- Short life & Maintenance cost is high

FUEL CELL

- **A fuel cell is a device which use hydrogen and oxygen to create an electric current**

Types of fuel cell:

- **Polymer electrolyte membrane fuel cell**
- **Direct methanol fuel cell**
- **Alkaline fuel cell**
- **Phosphoric acid fuel cell**
- **Molten carbonate fuel cell**
- **Solid oxide fuel cell**
- **Reversible fuel cell**

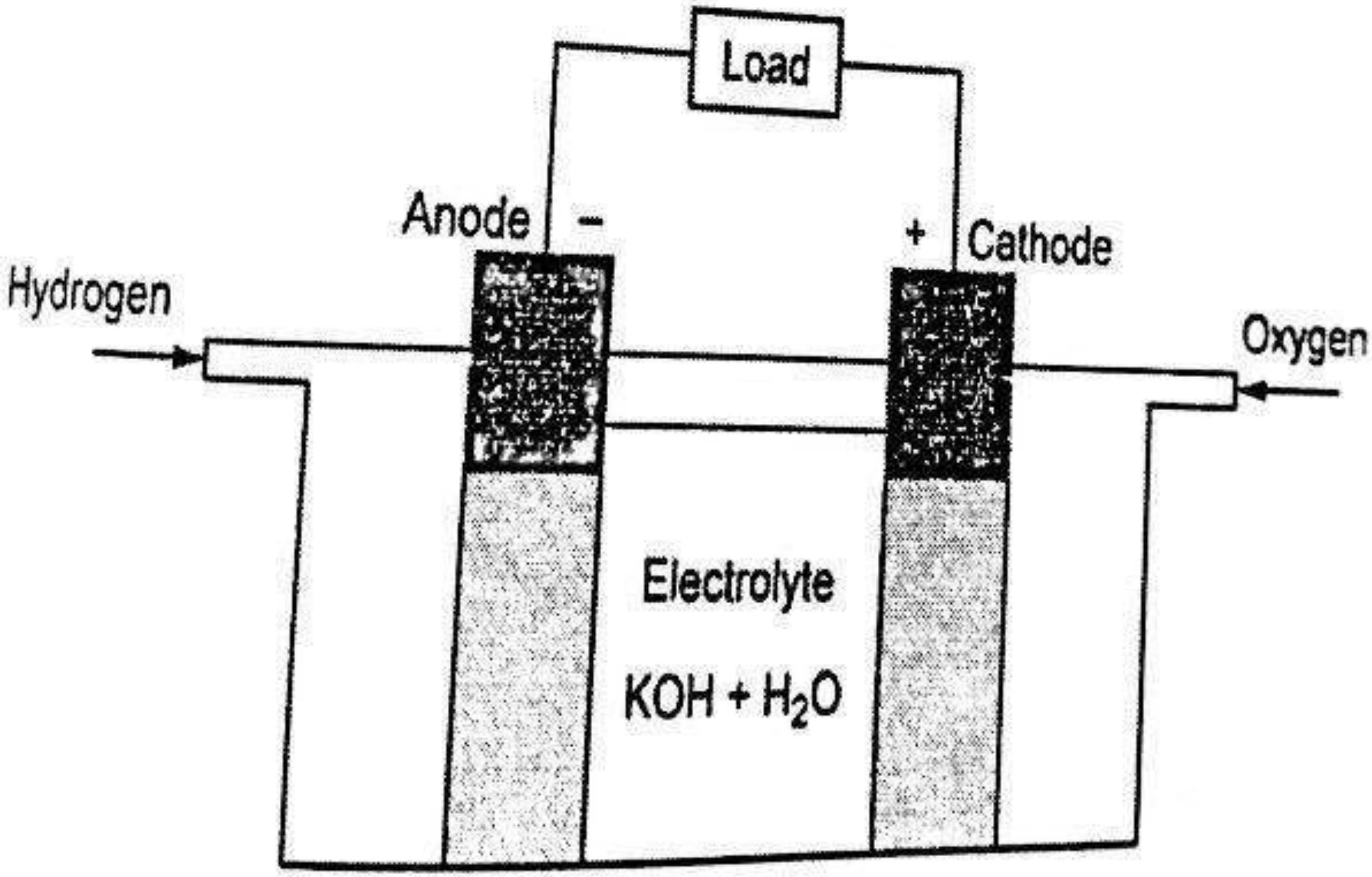
Components Of A Fuel Cell

- Membrane electrode assembly

  a) Anode

  b) Cathode
- Catalyst
- Chemistry of fuel cell

Hydrogen – Oxygen Fuel Cell



Two types of hydrogen fuel cell,

1. Low temperature cell

   Temperature = 90^0C Pressure

   = 4 atmospheric

2. High Pressure cell

   Temperature = 300^0C

   Pressure = 45 atmospheric

Advantages

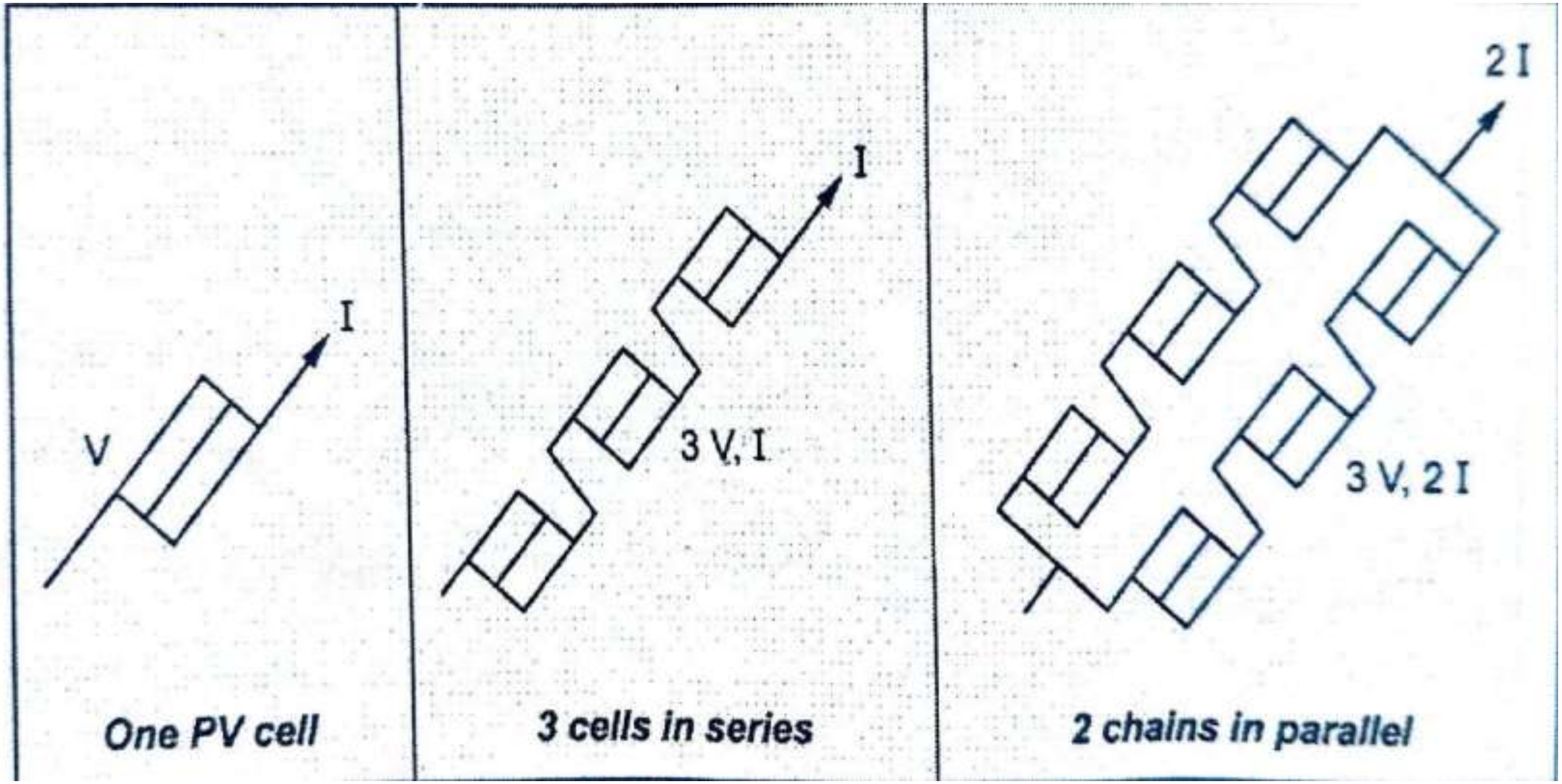
- **Fuel cells eliminate pollution caused by burning fossil fuels, the only by- product is water.**
- **The maintenance of fuel cells is simple since there are few moving parts in the system.**
- **Use variety of fuels, renewable energy and clean fossil fuels.**
- **Fuel cells can be responsive to changing electrical loads.**
- **Fuel cells provide high quality DC power.**

Disadvantages

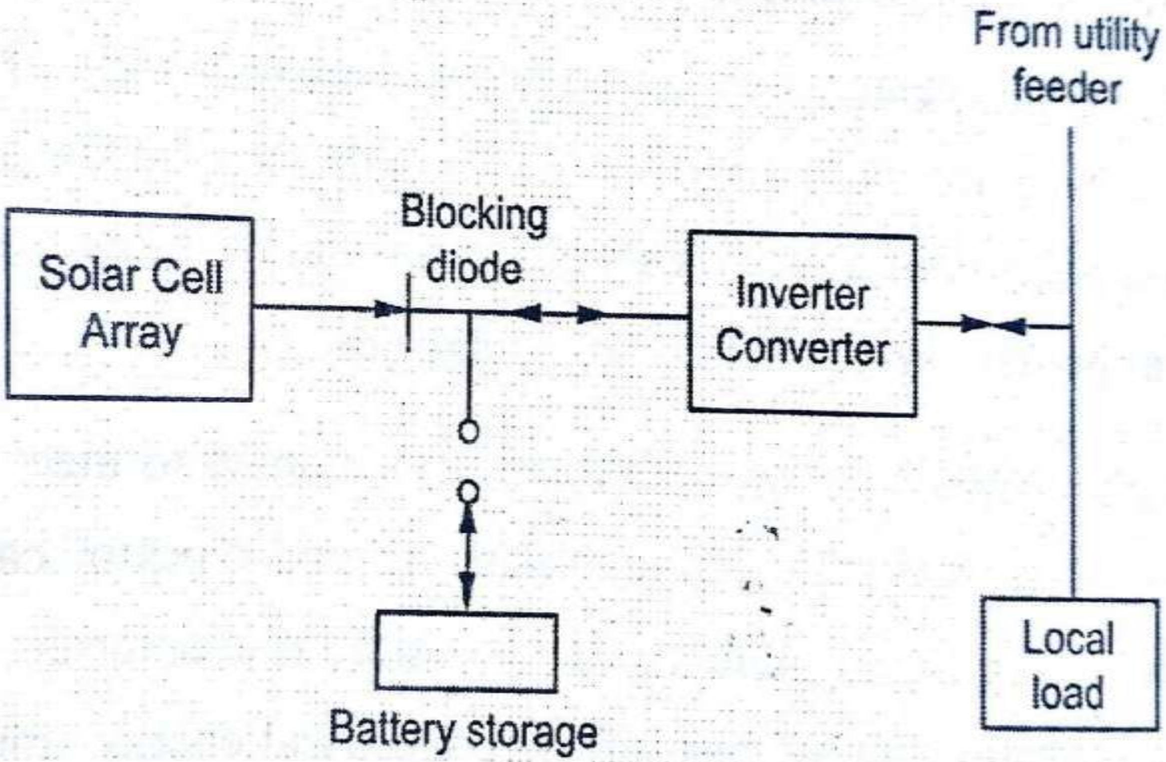
- Initial cost is high & fuel cells are currently very expensive to produce since most units are hand made.
- Service life is low. Operation requires frequent fuel supply.
- The technology is not yet fully developed and few products are available

SOLAR ENERGY

Solar PV cell



Solar PV power generation system



SOLAR ENERGY

The collectors receives the heat from solar rays and transfer to the fluid

Two types of collectors,

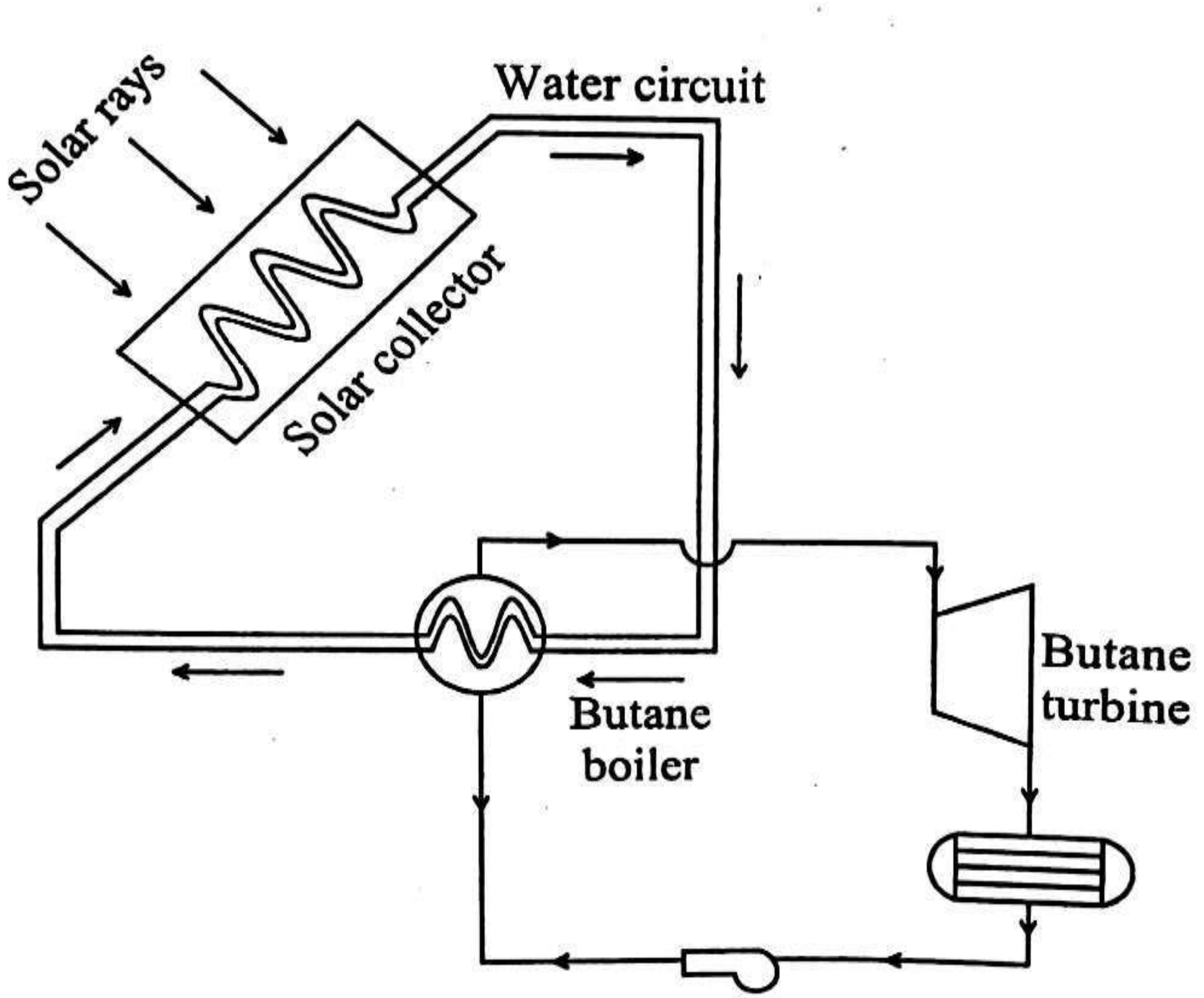
1.Flat plate (or) Non concentration collector

2.Focusing (or) Concentration collector

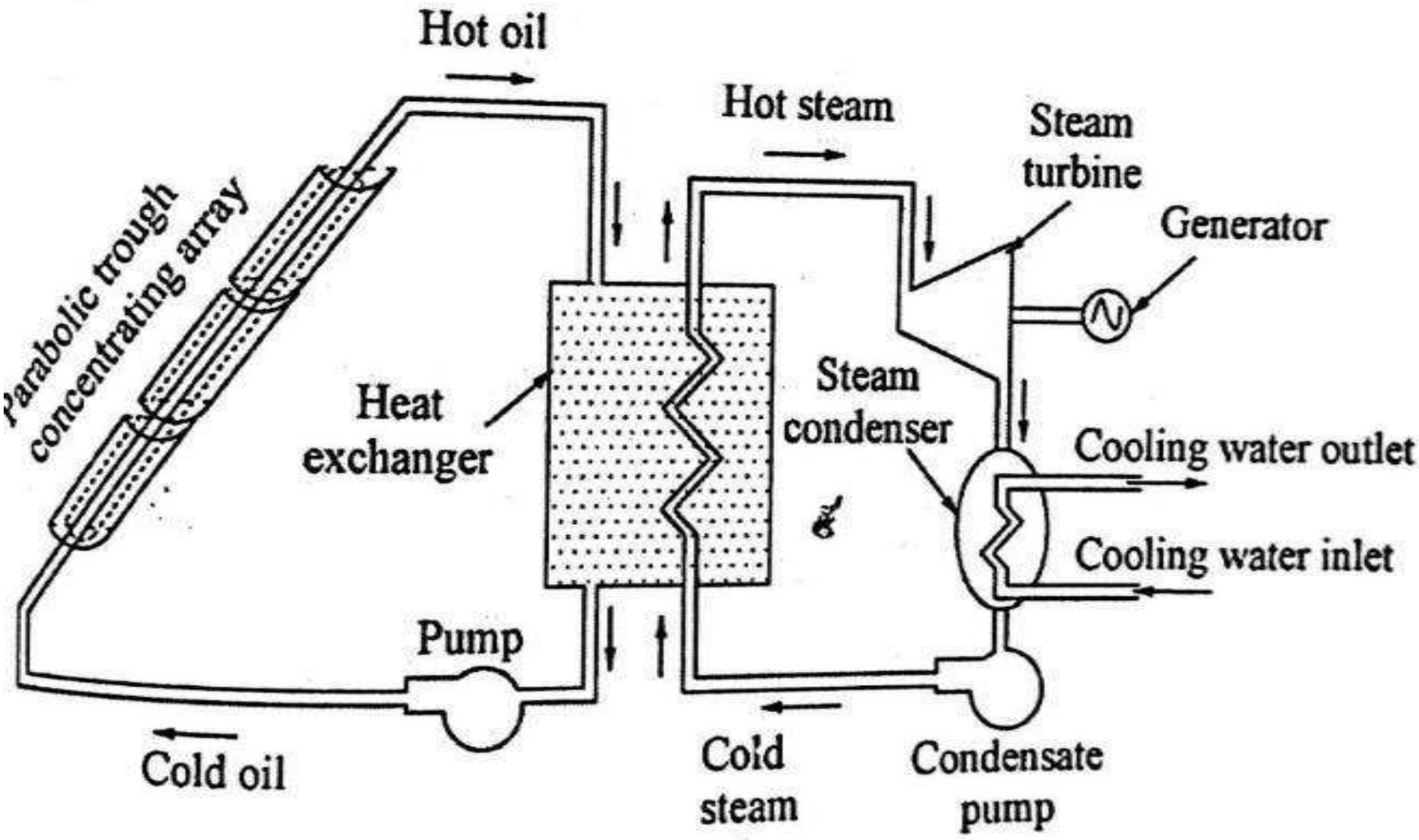
Features Of Collectors

- **Type of collectors**
- **The temperature of working fluid (Low (or) Medium(or) High)**
- **Cost of solar collector**
- **Design of solar collector system**

Flat Plate Collector



Focusing Collector



Types of concentrating collectors:

- **Parabolic trough collector**
- **Mirror strip collector**
- **Fresnel less collector**
- **Flat plate collector with adjustable mirrors**
- **Compounded parabolic concentrator**

Application

1. Heating water
2. Cooking
3. Boiling water, which may intern be used for producing power

IAE –II

UNIT- III

1. Chain reaction & types
2. Components of reactor
3. Working of BWR
4. Working of PWR
5. Working of FBR
6. Working of CANDU type reactor
7. Working of Gas cooled reactor (Refer note)
8. Uranium Enrichment

IAE –II

UNIT- IV

1. Essential components (or) Layout of Hydro power plant
2. Pumped stored power plant (Refer note)
3. Working of Pelton wheel
4. Tidal Energy & Types
5. Geo thermal Energy & Types (Refer note)
6. Bio gas power plant & Types
7. Solar PV power generation system
8. Type of solar power generation
9. Fuel cell & Types
10. Wind energy& Types

UNIT - V

ENERGY, ECONOMIC
&
ENVIRONMENTAL ISSUES OF POWER PLANTS

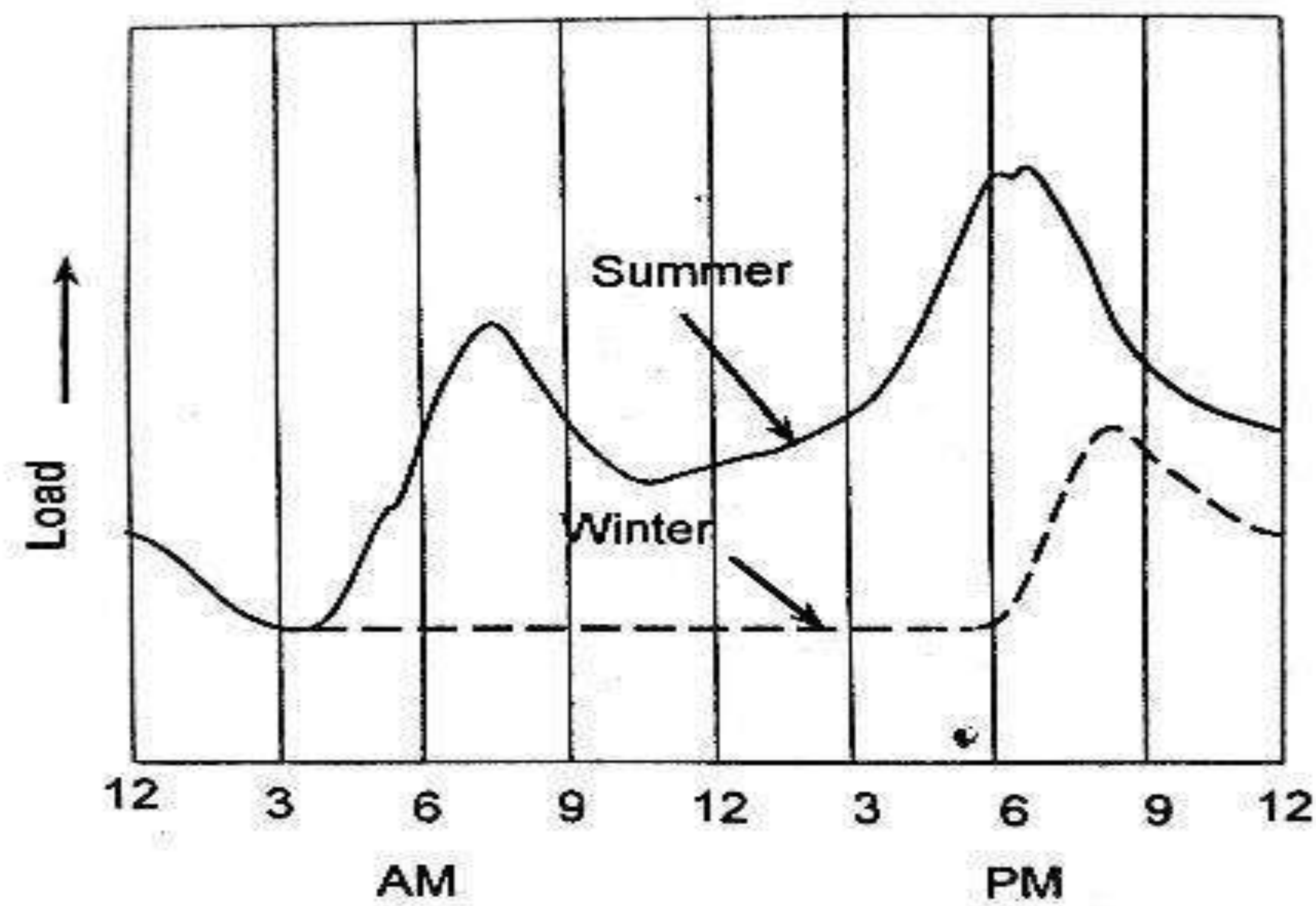
Load Curve

- **It is a graphical representation which shows power demands for every instant during a certain time period**
- **It is drawn between Load(KW) and Time(Hr's)**
- **If it is plotted for 1 hour, it is hourly load curve**
- **If it is plotted for 24 hours, it is daily load curve**
- **If it is plotted for One years, it is Annual load curve**

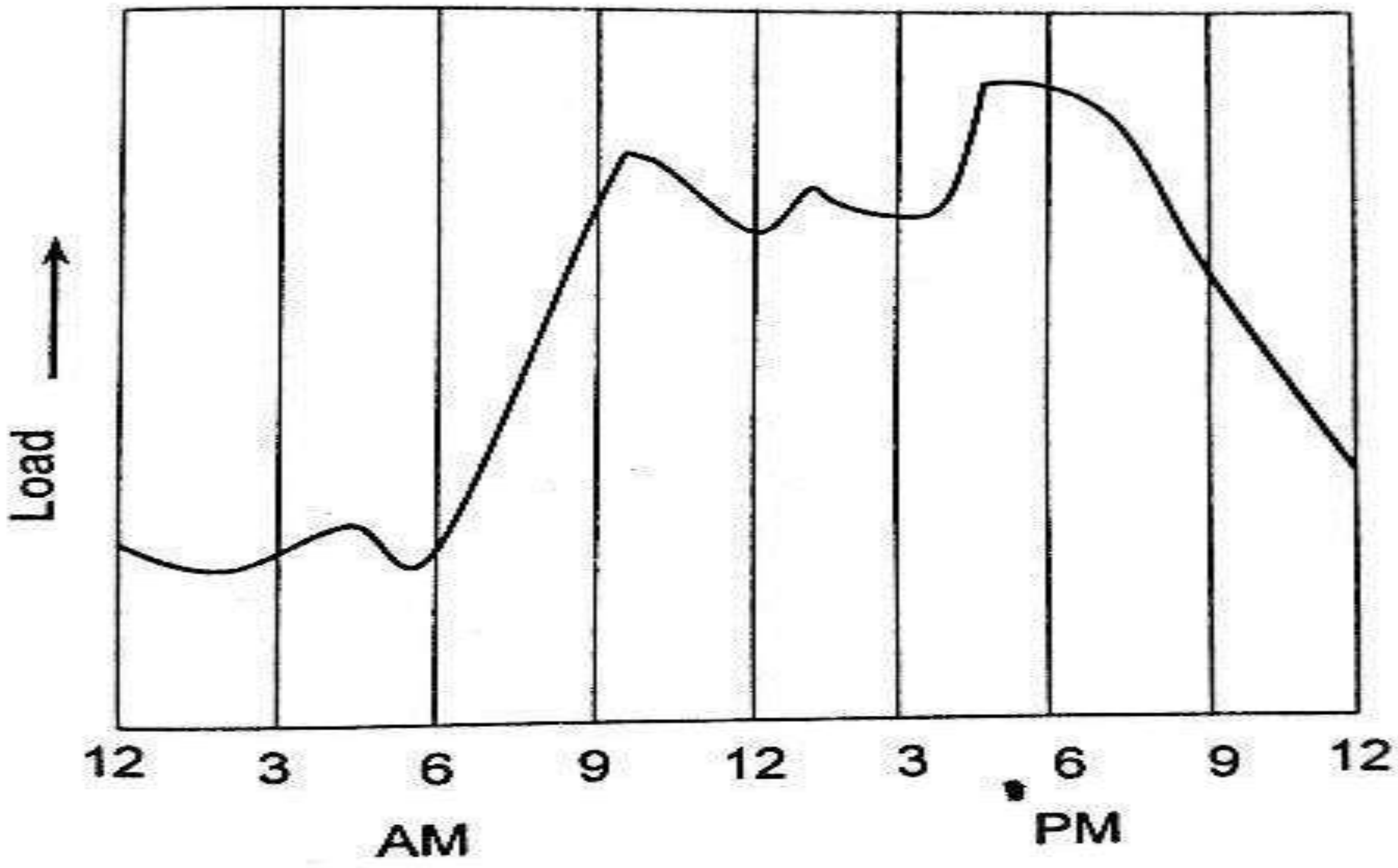
Load Distribution Parameters

- **Residential Load**
- **Commercial Load**
- **Industrial Load**
- **Municipal Load**
- **Irrigation Load**
- **Traction Load**

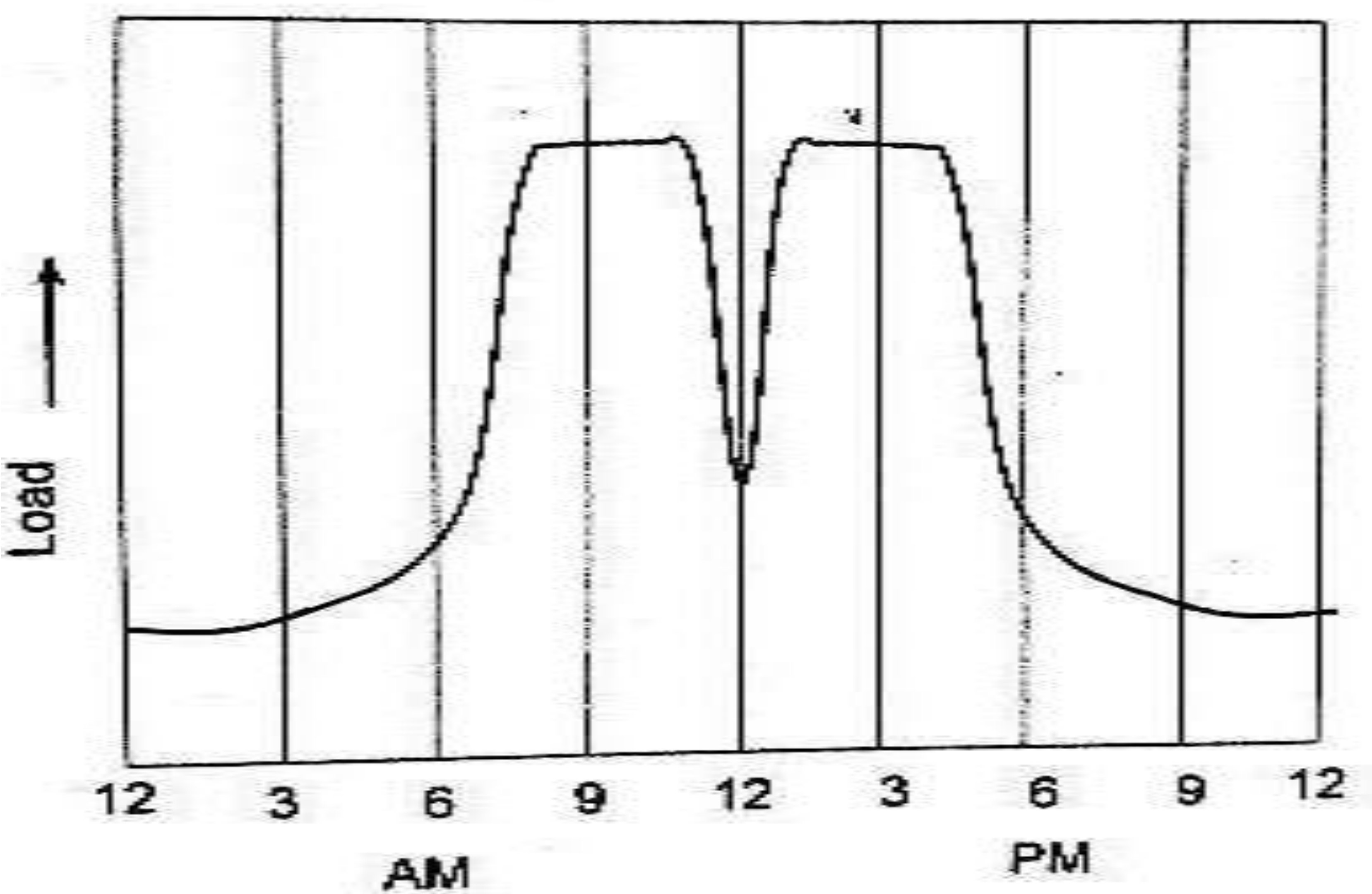
1. Residential Load Curve



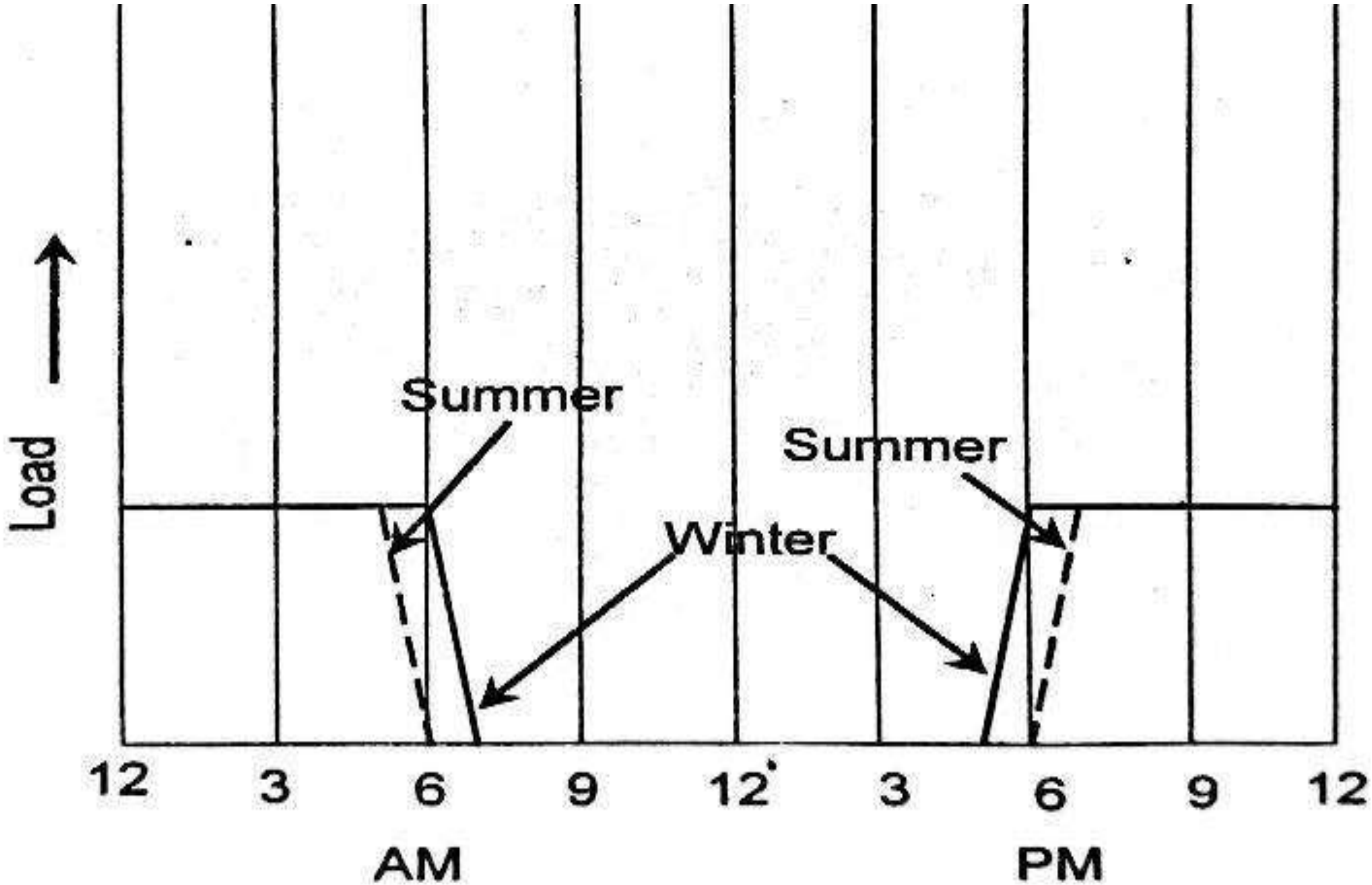
2. Commercial Load Curve



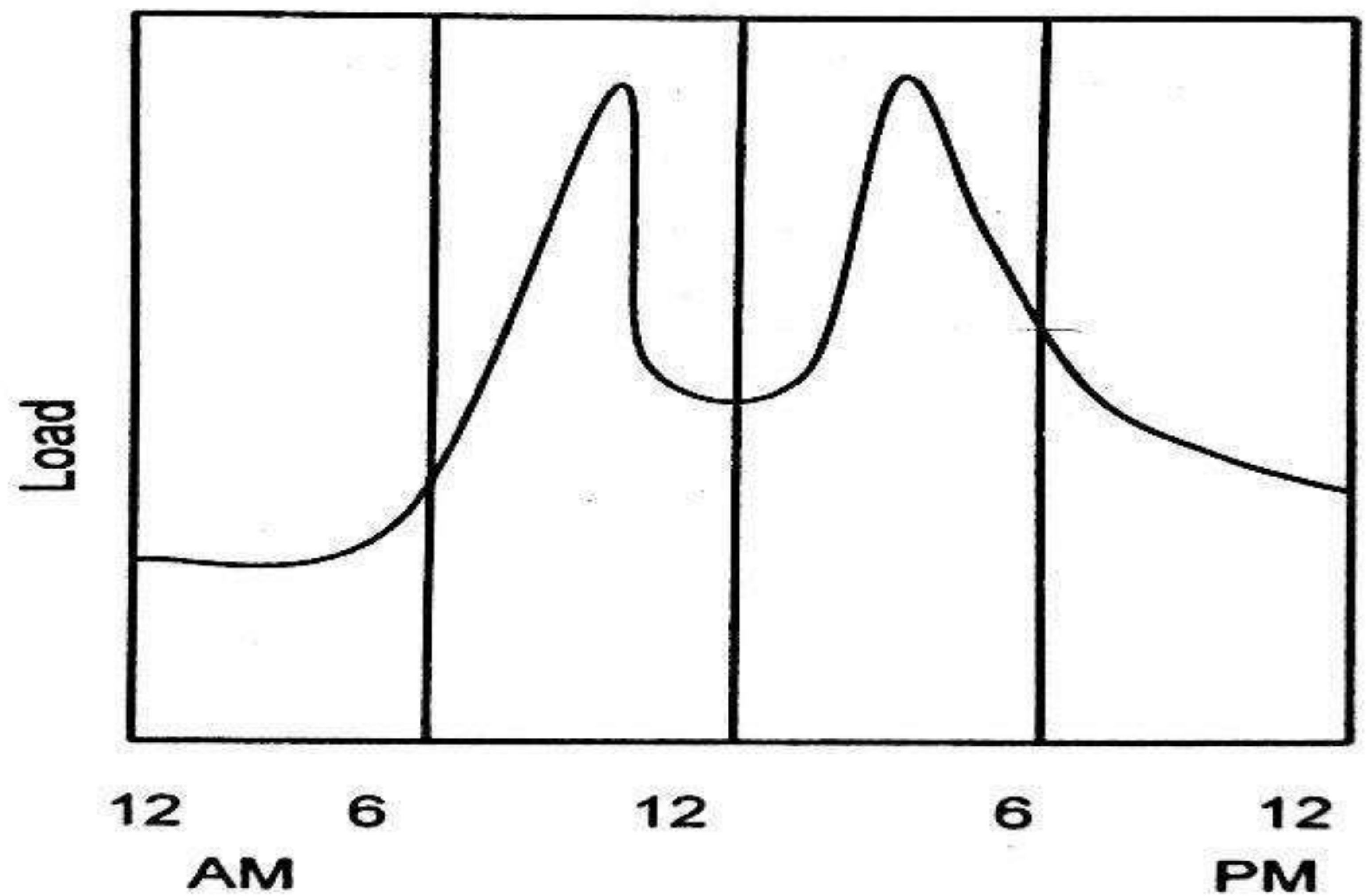
3. Industrial Load Curve



4. Street Light Load Curve



5. Urban Traction Load Curve



Important Terms:

1) Connected Load

2) Demand

3) Maximum demand

4) Demand Factor = $\dfrac{Maximum\ (or)\ Peak\ demand}{Total\ connected\ Demand}$

5) Load Factor = $\dfrac{Average\ Load}{Peak\ Load\ (or)\ maximum\ demand}$

6) Capacity Factor

$$= \frac{Average\ load}{Plant\ Capacity} = \frac{E}{C\, x\, t}$$

Where, E = Energy produced(kWhr)

C = Capacity of the plant (kW)

t = Total No of hr's

7) Utilization Factor = $\dfrac{Maximum\ Load}{Rated\ Capacity\ of\ the\ plant}$

8) Reserve Factor = $\dfrac{Load\ Factor}{Capacity\ Factor}$

8) Diversity Factor = $\dfrac{Sum\ of\ the\ individual\ maximum\ demand}{Annual\ peak\ load}$

TARIFF (or) ENERGY RATE

Objectives of tariff:

- **Recovery of cost of capital investment in generating equipment, transmission and distribution system**
- **Recovery of the cost of operation, supplies and maintenance of the equipment**
- **Recovery of the cost of material, equipment, billing and collection cost as well as for miscellaneous services**
- **A net return on the total capital investment must be ensured**

Requirements Of Tariff

- It should be easier to understand
- It should provide low rates for high consumption
- It should be uniform over large population
- It should encourage the consumers having high load factors
- It should take into account maximum demand charges and energy charges
- It should provide incentive for using power during off-peak hours..etc

General Tariff Form

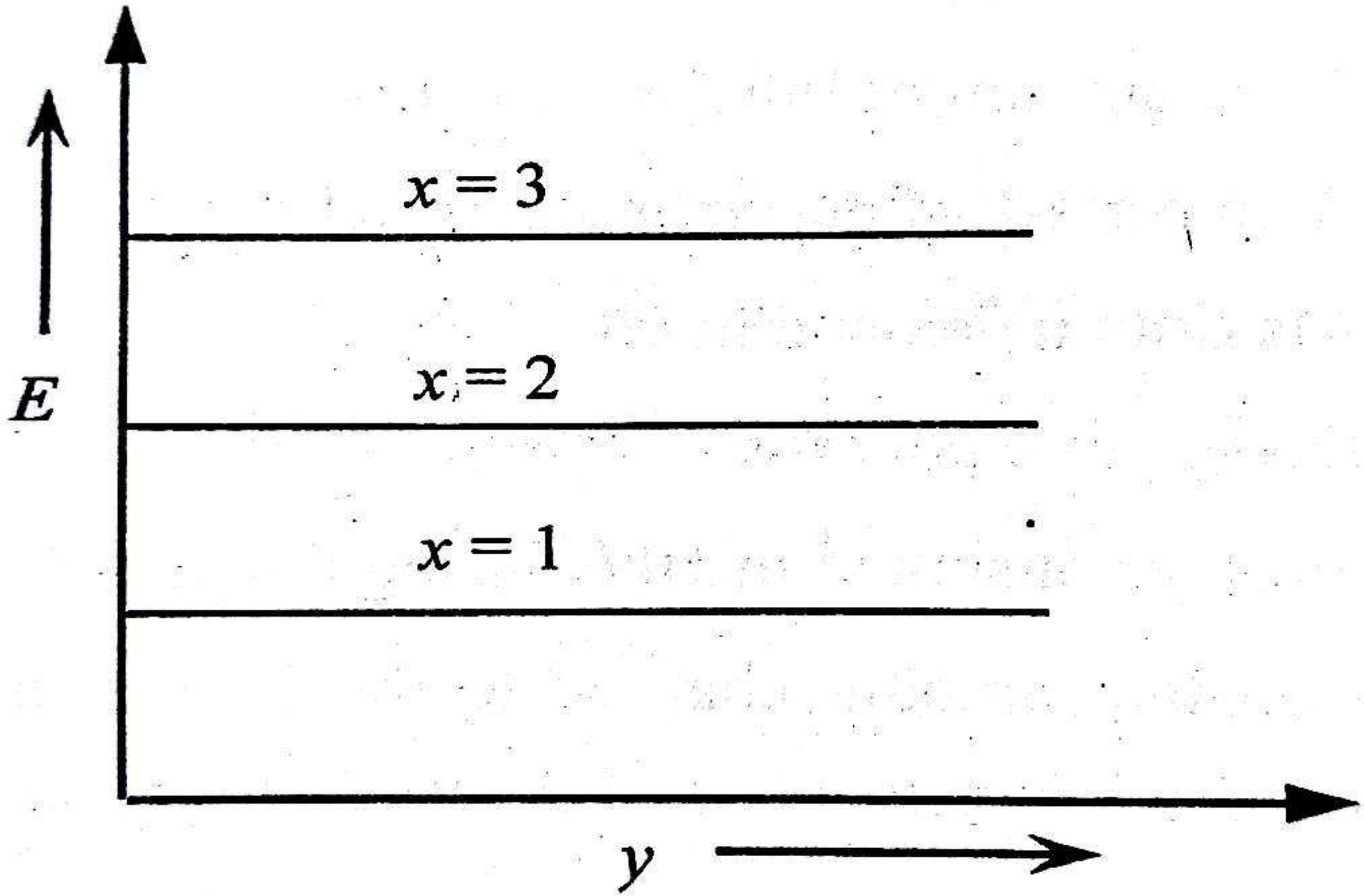
- **A large number of tariff forms have been framed time to time and are in use. All these different types are derived from the following general equation.**

$$Z = A \times X + B \times Y + C$$

Types Of Tariffs

1. Flat demand rate
2. Straight line meter rate
3. Block-meter rate
4. Hopkinson or Tow-part tariff
5. Doherty or Three-part tariff

1. Flat demand rate



E = AX

E = Total amount of bill for the period considered

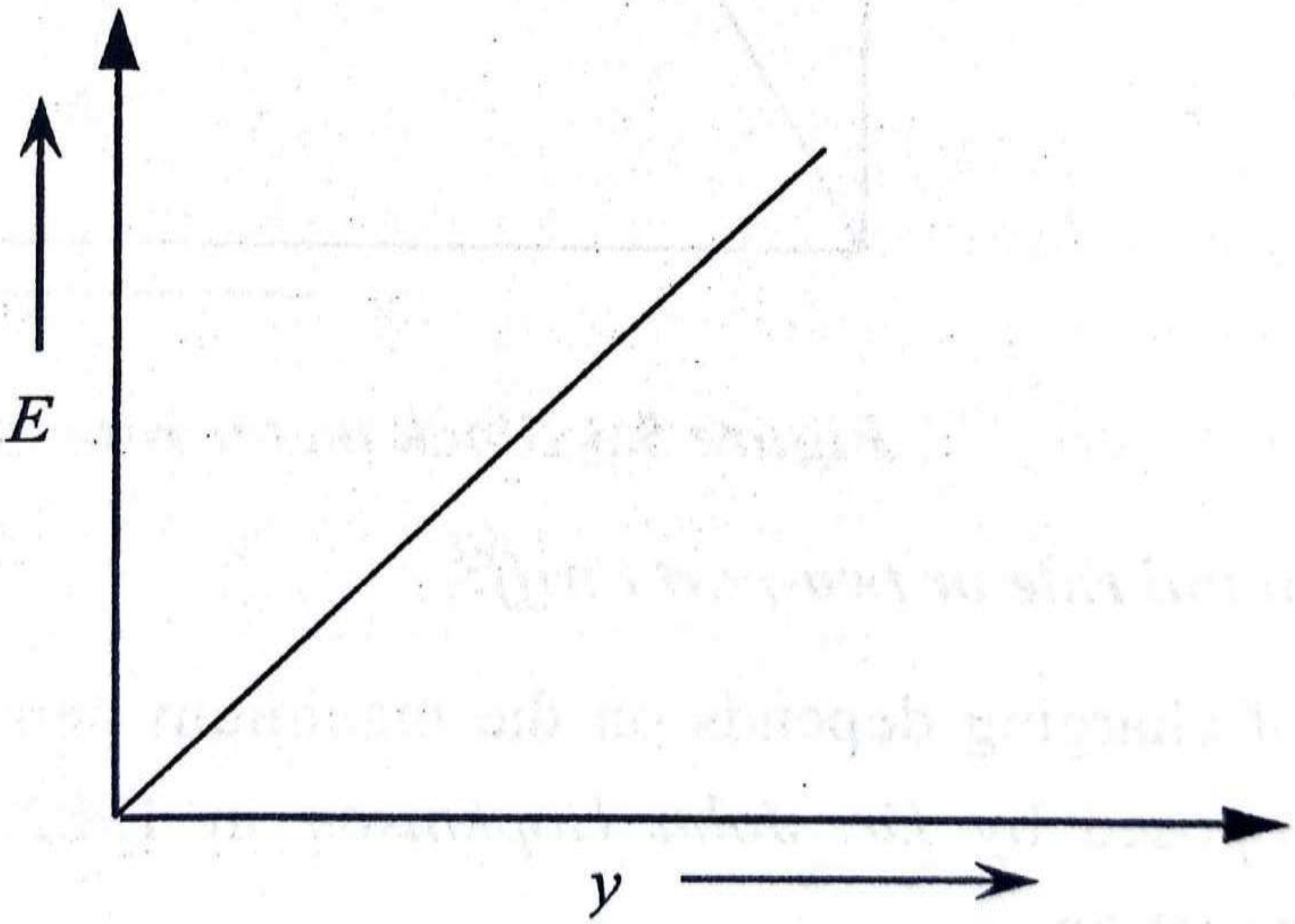
A = Rate per KW of maximum demand

X = Maximum demand in KW

Application:

1. **Signal system**
2. **Street Lighting**
3. **Irrigation tube well**

2. Straight line meter rate



E = B Y

E = Total amount of bill for the period considered

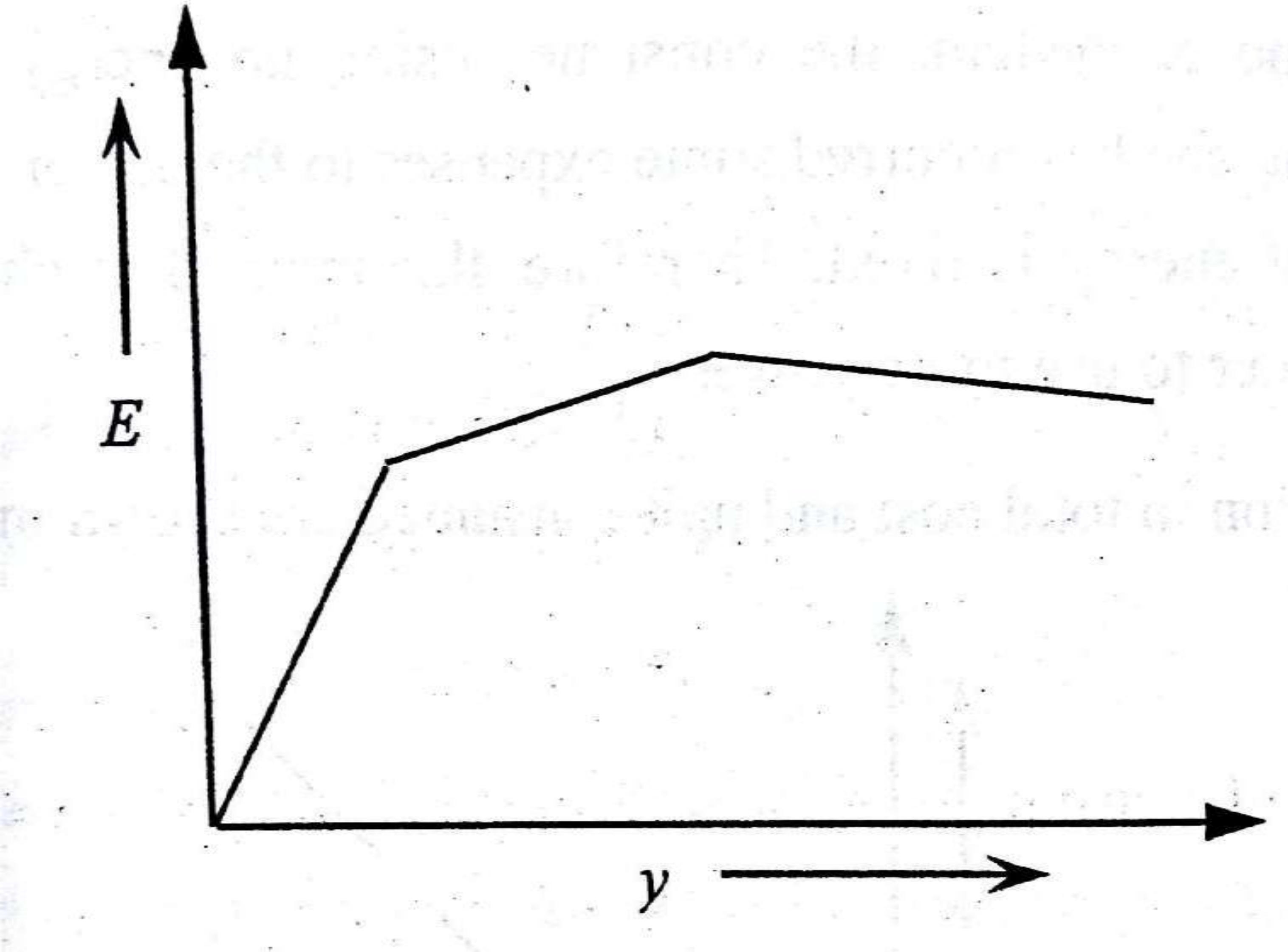
B = Energy rate per KWh

Y = Energy consumed in KWh during the period

Application:

1. **Residential**
2. **Commercial**

3. Block-meter rate



$$E1 = B_1Y_1 + B_2Y_2 + B_3Y_3 + \ldots$$

Where,

$Y_1 + Y_2 + Y_3 + \ldots\ldots = Y$ (Total energy consumption)

B1,B2&B3 are unit charges

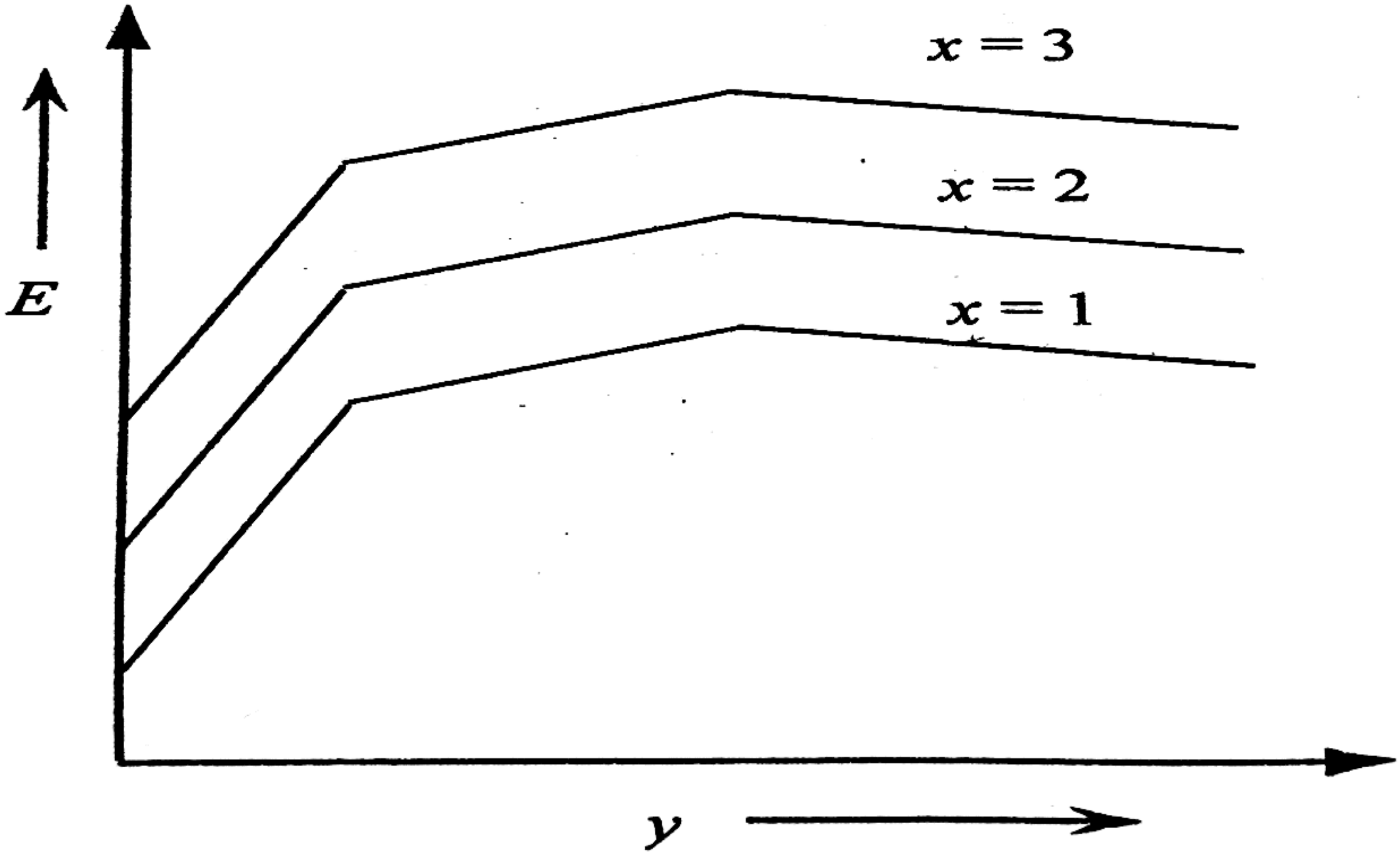
B3 < B2 < B1

Application:

1. Residential

2. Commercial

4. Hopkinson (or) Tow-part tariff



E = A + BY

E = Total amount of bill for the period considered

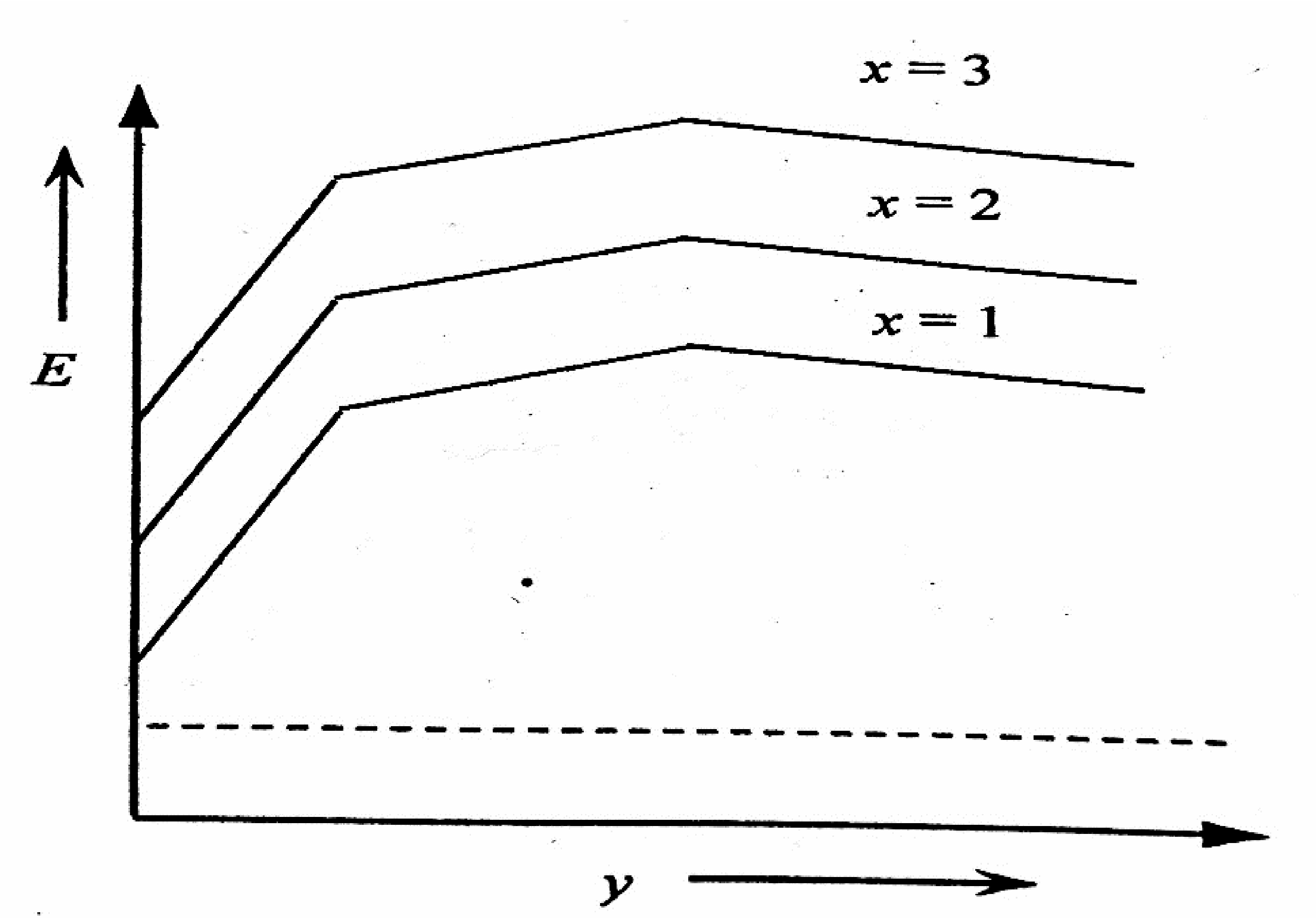
B = Energy rate per KWh

Y = Energy consumed in KWh during the period

Application:

1. Industrial

5. Doherty or Three-part tariff



E = AX +BY + C

Where,

E = Total amount of bill for the period

A = Rate per KW of maximum demand

X = Maximum demand in KW

B = Energy rate per KWh

Y = Energy consumed per KWh

C = Constant amount charged

Application:

1. Industrial

Nuclear Waste Disposal

Types of Nuclear Waste,

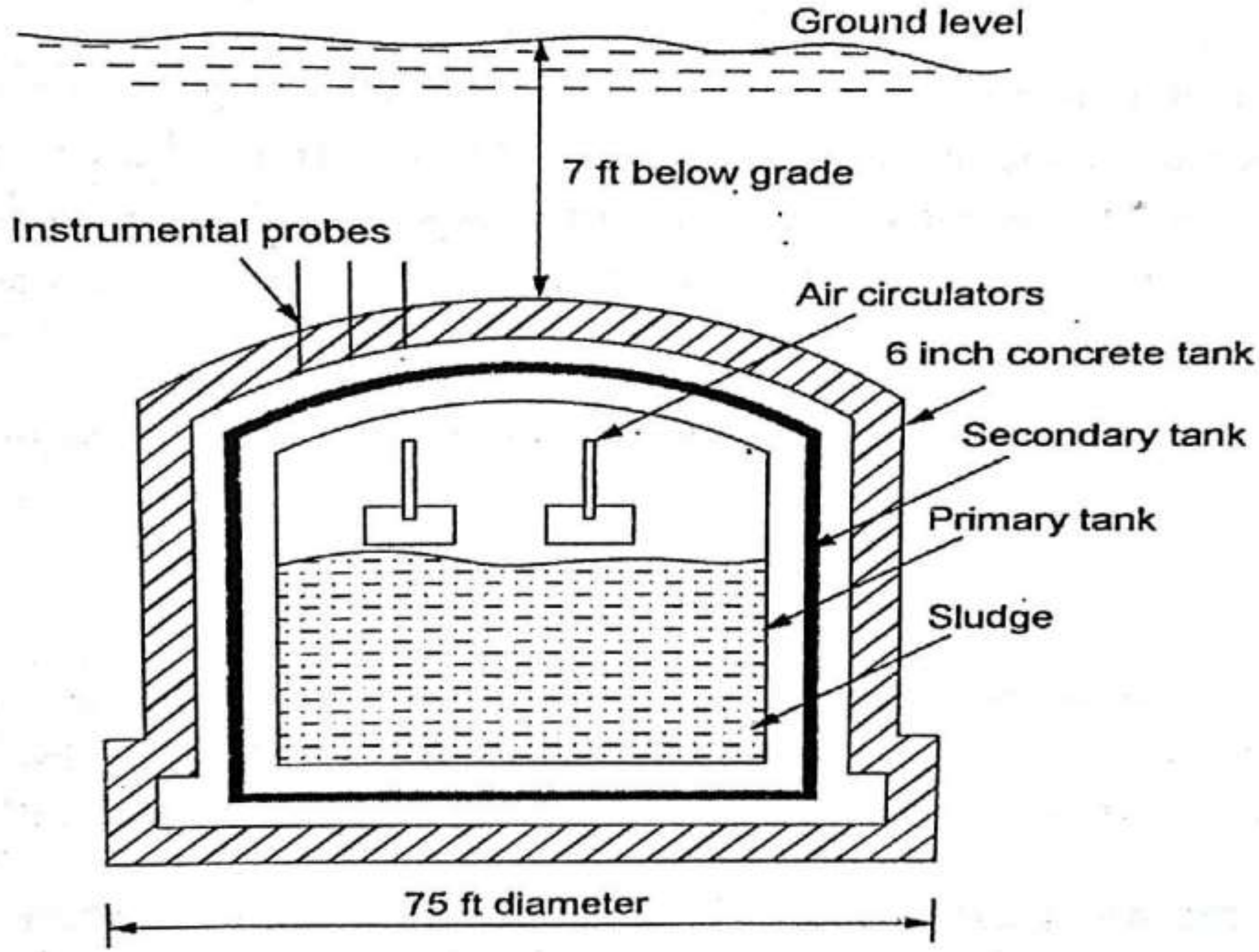
a) On the basis of half-life time

- **i) Fission products**
- **ii) Actinides**
- **iii) The neutron activation products**

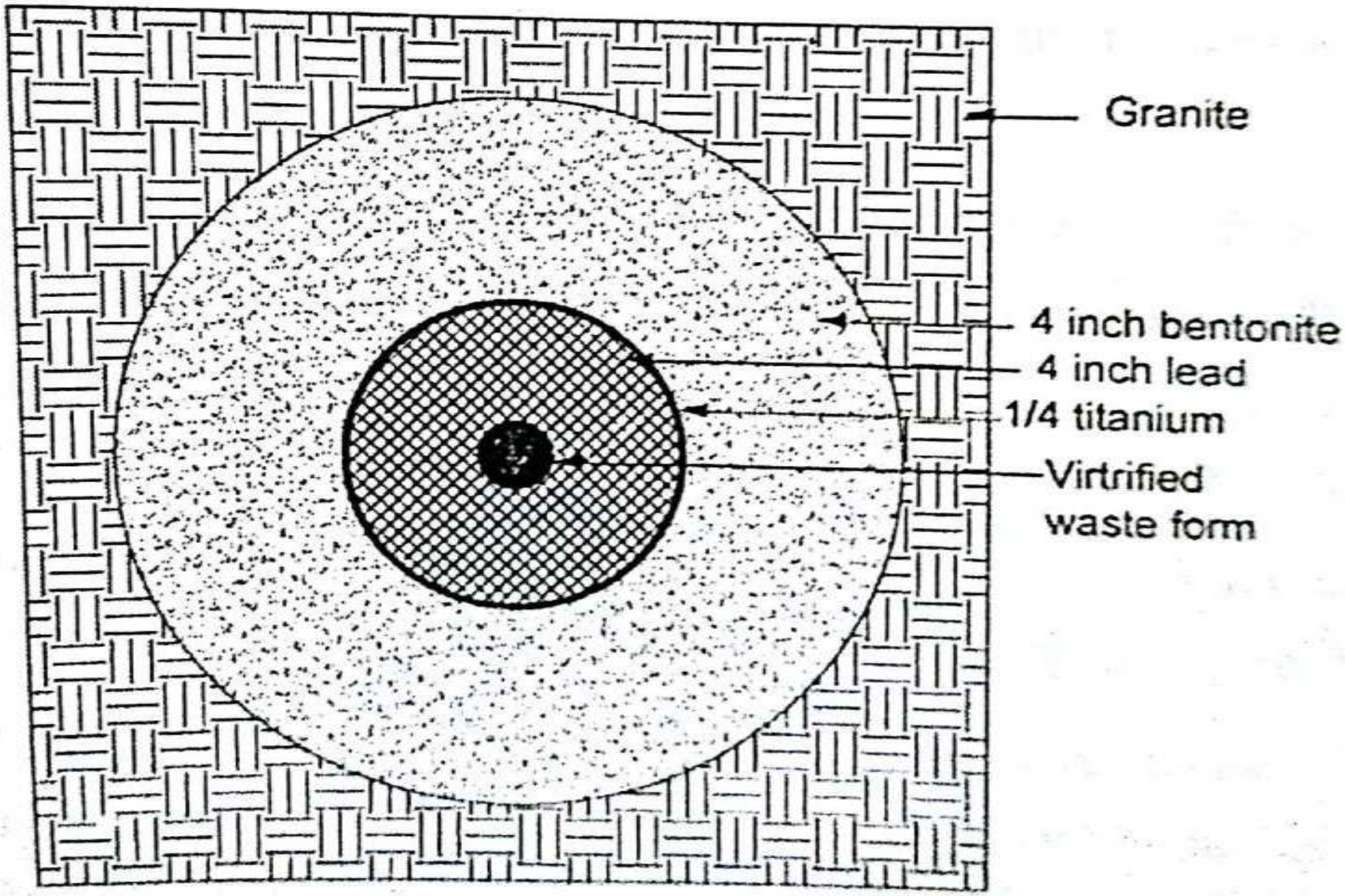
b) On the basis of the intensity of radiation

- **i) Low level waste**
- **ii) Medium level waste**
- **iii) High level waste**

Disposal of Low level solid waste



Underground Disposal of High level waste



Thermal Power plant Waste Disposal

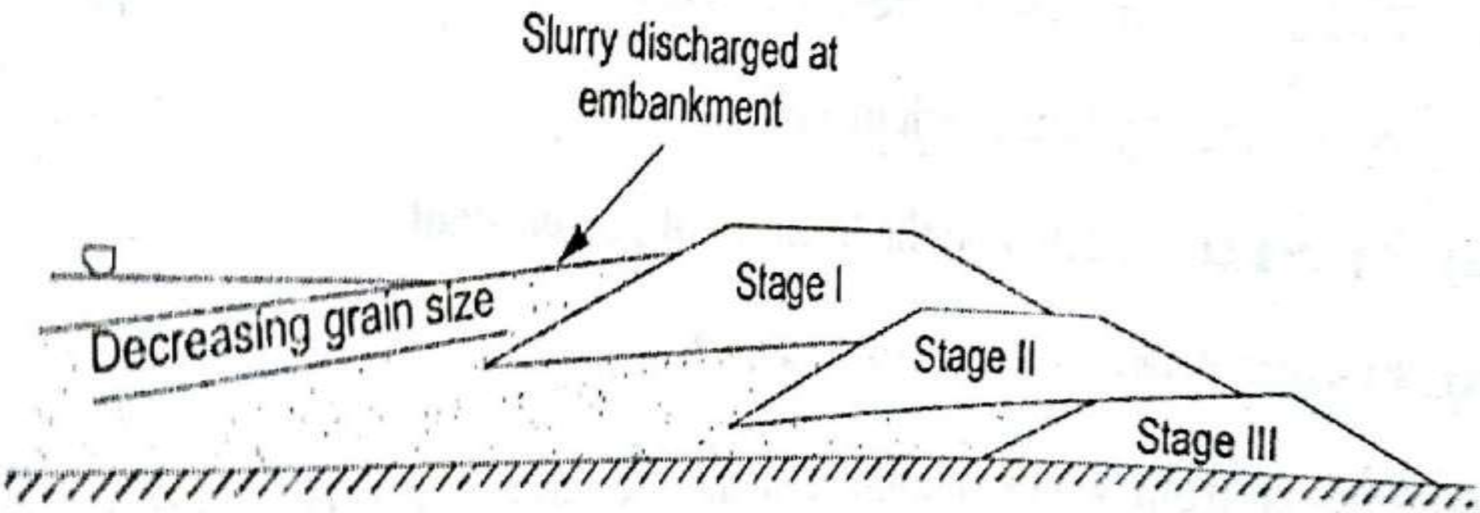
Methods,

1) **Upstream Method**

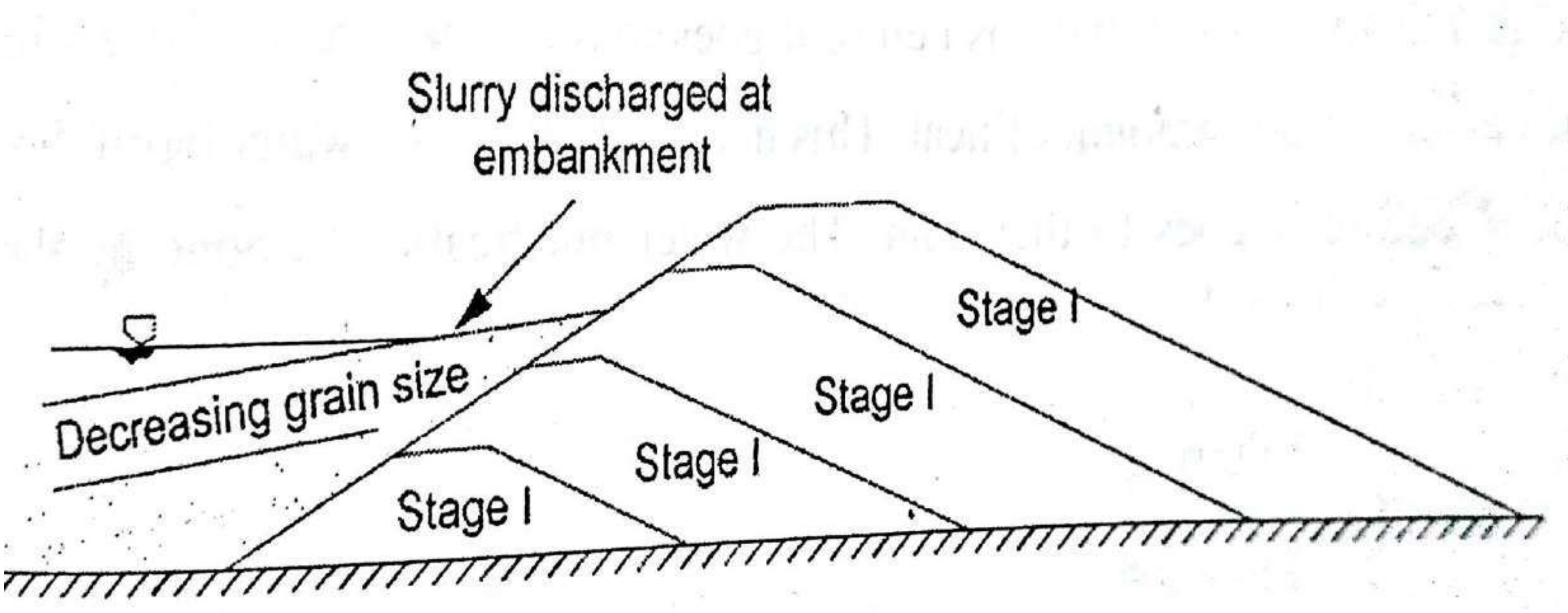
2) **Downstream Method**

3) **Centerline Method**

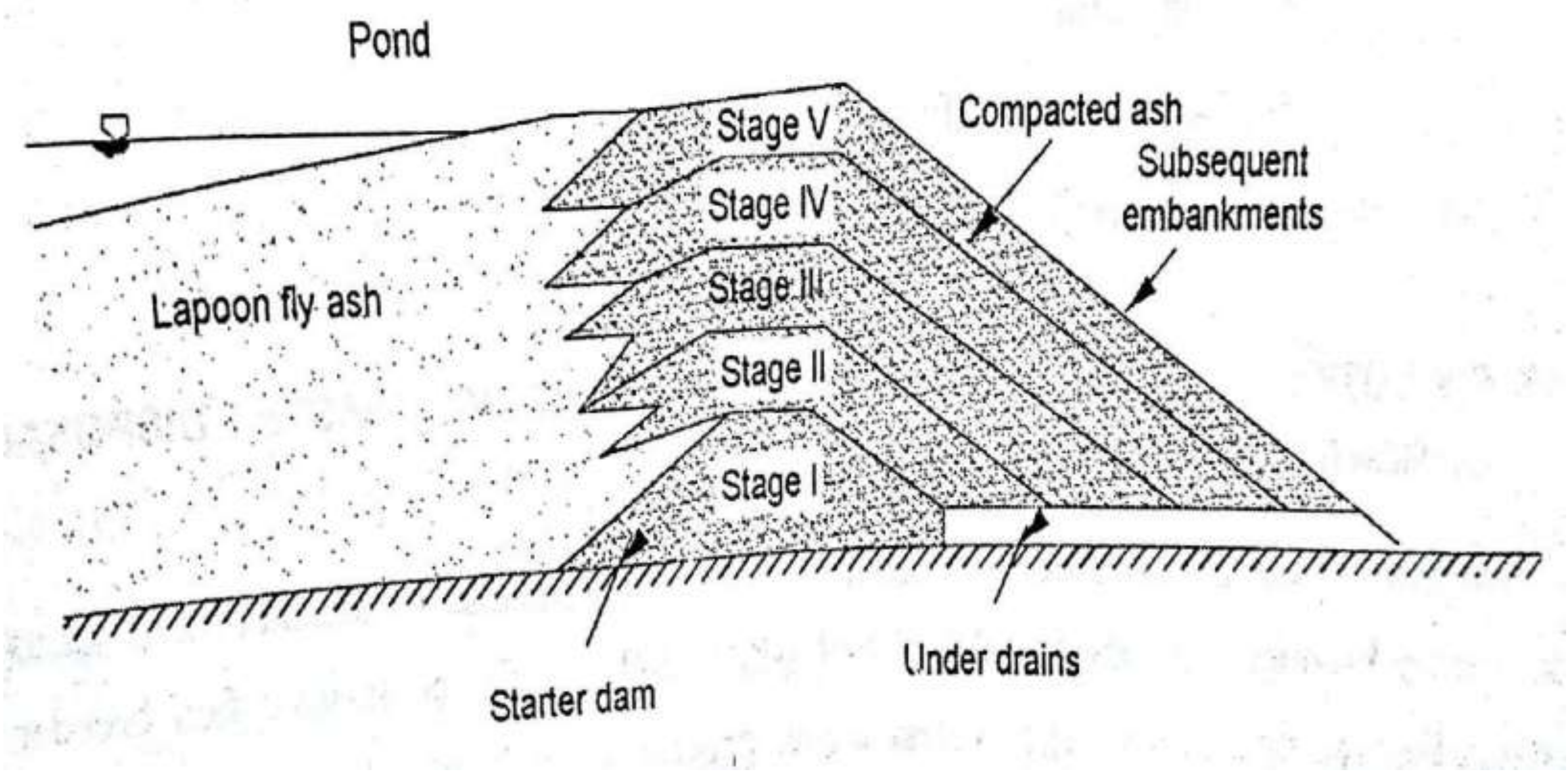
a) Upstream Method



b) Down stream Method



c) Center line Method



Pollution Control Technology

Emissions can be classified into four types,

1. **Gaseous emission**
2. **Particulate emission**
3. **Solid waste emission**
4. **Thermal pollution**

1. Gaseous Emission

a) Sulphur dioxide (SO_2)

b) Nitrogen oxides (NO_x)

c) Hydrogen Sulphide

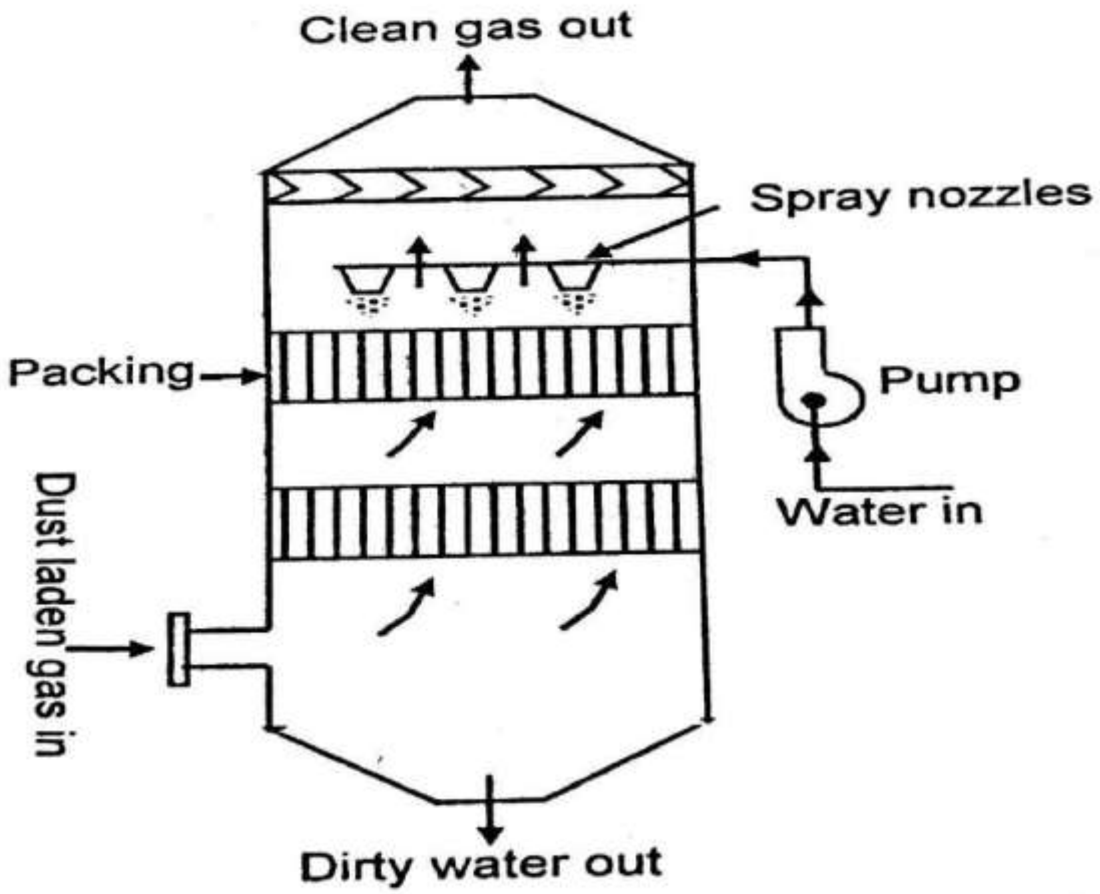
d) Carbon Monoxide (CO)

Effect of pollutants

S. No	Pollutant	On man	On vegitation	On materials/ animals
1.	SO_2	Suffocation, irritation of throat and eyes,respiration system	Destruction of sensitive crops and reduced yield	Corrosion
2.	NO_2	Irritation, bronchitis, oedema of lungs.	—	—
3.	H_2S	Bare disease, respiratory diseases.	Destruction of crops.	Flourosis in cattle grazing.
4.	CO	Poisoning, increased accident-liability	—	—

1. Removal of SO_2

- **SO2 is removed by wet scrubber and separate the particular matters**



Application of Wet scrubber

1) Chemical Industry

2)Grain milling industry

Emission of NOx:

Air + fossil fuel → NO2

The resulting mixture is represented by NOx

Methods are used to reduce NOx emission,

- **Reducing of residence period in combustion zone**
- **Reducing of temperature in combustion zone**
- **Increase in equivalence ratio in combustion chamber**

2. Particulate emission

The particular matters are,

1) Dust(1 micron) Which do not settle down

2)Particles (10 microns) which settle down to the ground

Particles can be classified,

a) Smoke (less than 10 micron)

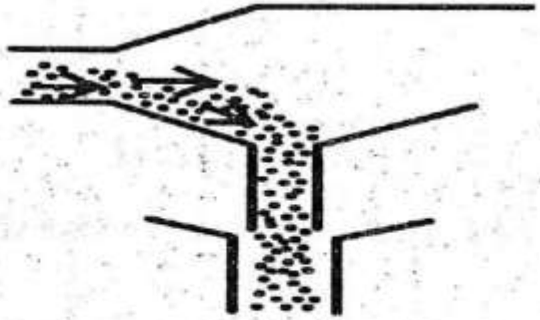
b) Fumes

These are very small particles which is obtained from chemical reaction

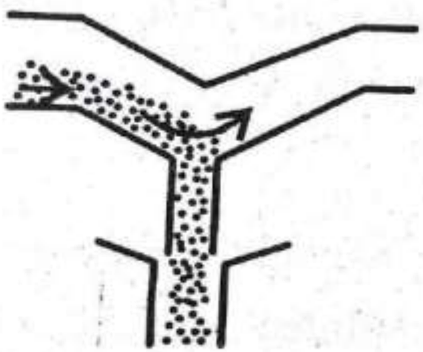
c) Fly- ash (equal to 100 microns)

d) Cinders (more than 100 microns)

Cinders,



Sudden decrease in gas velocity



Sudden change in the direction of the flow of flue gas

PROBLEMS

1) The peak load on a thermal power plant is 75 MW. The loads having maximum demands of 35MW,20MW,15MW and 18MW are connected to the power plant. The capacity of the power plant is 90MW and the annual load factor is 0.53. Calculate: a) Average load on the power plant b) Energy supplied per year c) Demand factor d) Diversity factor

Solution:

a) Load factor $= \dfrac{Average\ Load}{Peak\ Load}$

$$0.53 = \frac{Average\ Load}{75}$$

Average load = 0.53 x 75

= **39.75 MW**

b) Energy supplied per year = Average Load x 24 x 365

= 39.75 x 8760

= **348210 MW hr**

c) Demand Factor = $\dfrac{\text{Annual Peak Poad}}{\text{Sum of the individual peak Load}}$

$$= \frac{75}{35+20+15+18}$$

$$= 0.852$$

d) Diversity factor = $\dfrac{\text{Sum of the individual peak Load}}{\text{Annual peak Load}}$

$$= \frac{35+20+15+18}{75}$$

$$= 1.173$$

2) The yearly duration curve of a certain plant can be considered as a straight line from 400 MW to 100 MW. Power is supplied with one generation unit of 250MW capacity and two units of 125 MW capacity each. Determine: a) Installed capacity b) Load factor c) Capacity factor d) Maximum demand e) Utilisation factor

Solution:

a) Installed capacity

$$= 1 \times 250 + 2 \times 125$$

$$= 500 \text{ MW}$$

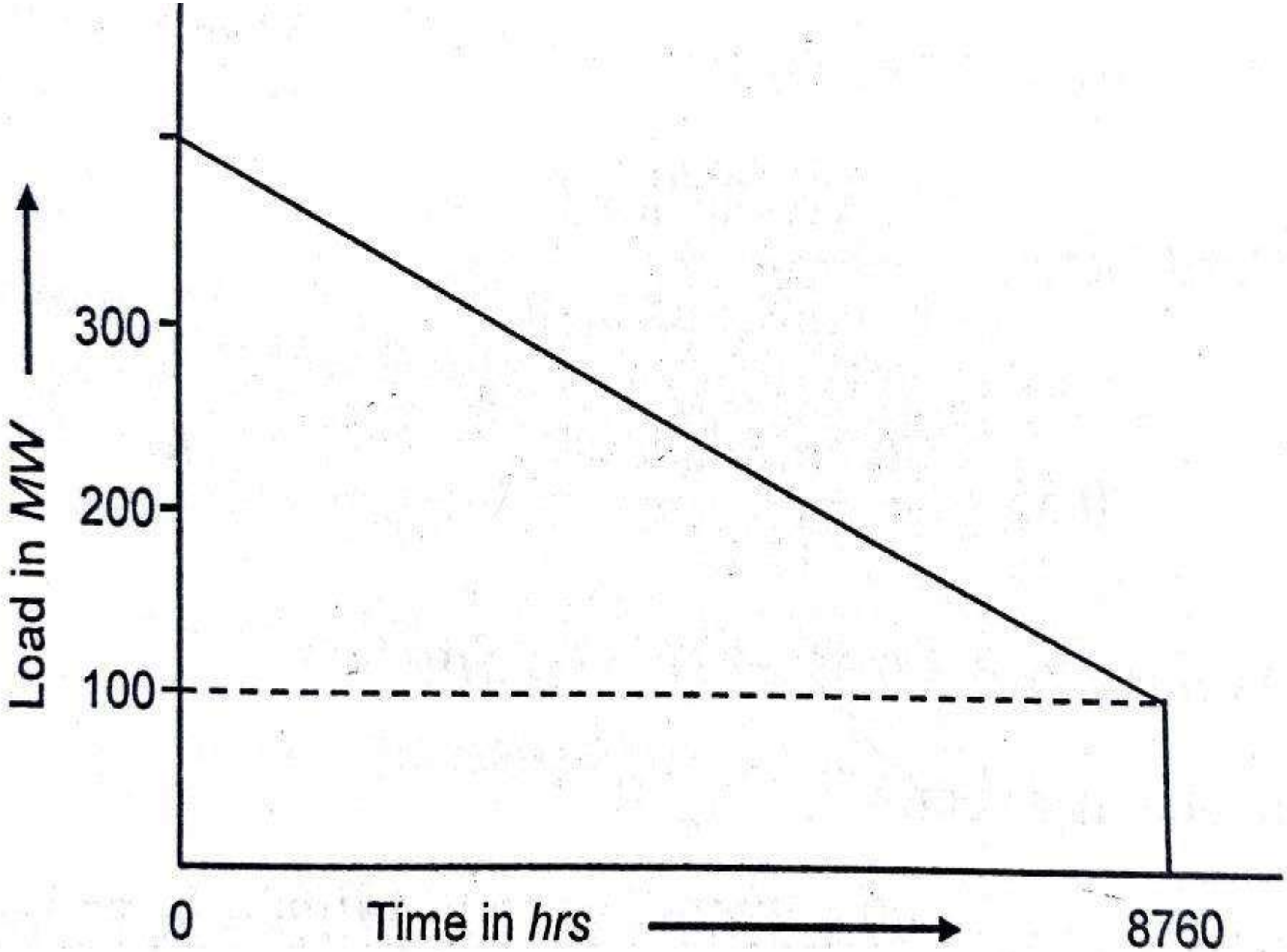
b) Load factor

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$\text{Average Load} = \frac{\text{Area under the load curve}}{\text{Number of hours in the period}}$$

For one year duration,

$$24 \times 365 = 8760 \text{ hrs}$$



Load in MW
300
200
100
0
Time in hrs
8760

Area under the load curve,

$$= 100 \times 8760 + 1/2\,(400 - 100) \times 8760$$

$$= 2190000 \text{ MW hr}$$

Average Load $= \dfrac{2190000}{8760} = 250 \text{ MW}$

Load factor $= \dfrac{\text{Average Load}}{\text{Maximum deman}} = \dfrac{250}{400} = 0.625$

c) Capacity factor $= \dfrac{\text{Average Load}}{\text{Plant capacity}} = \dfrac{250}{500} = 0.5$

d) Maximum demand = 400 MW

e) Utility factor $= \dfrac{\text{Maximum Load}}{\text{Plant capacity}} = \dfrac{400}{500} = 0.8$

3) A thermal power station consists of two 60 MW units each running for 7320 hrs a Year and one 30 MW unit running for 1800 hrs a year. The energy produced by the plant per year is 725 x 10^6 kWh. Determine the plant load factor and plant use factor. Assume that the maximum demand is equal to plant capacity.

Solution:

Total capacity of the power plant,

$$= 2 \times 60 + 30 = 150 \text{ MW} = 150 \times 10^3 \text{ kW}$$

$$\textbf{Average Load} = \frac{\textit{Energy produced per year}}{\textit{Number of hrs in the period}}$$

$$\textbf{Average load} = \frac{725 \times 10^6}{8760}$$

$$= 82726.56 \text{ Kw}$$

$$\textbf{Load factor} = \frac{\textit{Average Load}}{\textit{Maximum demand}}$$

$$= \frac{82762.56}{150 \times 10^3}$$

$$= 0.552 = 55.2\%$$

Use Factor = $$\frac{Annual\ energy\ production\ in\ given\ time\ period}{Maximum\ energy\ production\ by\ the\ plant}$$

Maximum energy produced by the plant,

= (2 x 60 x 7320) + (1 x 30 x 1800)

= 932400 MW hr

= 932.4 x 10^6 kW hr

Use Factor = $$\frac{725\ x\ 10^6}{932.4\ x\ 10^6}$$ **= 0.778**

4) The output of a generating station is 12 MW and annual load factor is 0.58. The annual cost of fuel for running the plant is Rs. 12 x 10^5 and the annual wages and taxes are Rs. 10 x 10^5. The capital cost of the plant is Rs. 700 x 10^5 and interest and depreciation charges are made 10% of the capital cost per annum. Determine the cost of generation.

Solution:

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$0.58 = \frac{\text{Average Load}}{12}$$

Average Load = 12 x 0.58 = 6.96 MW

Energy produced per year,

= 6.96 x (365 x 24)

= 60969.6 MW hr = 609.696 x 10^5 kWhr

Fixed cost = Cost of interest and depreciation

= 0.1 x 700 x 10^5 = Rs. 70 x 10^5

Running cost = Cost of fuel + Cost of wages and taxes

$= Rs.\ 12 \times 10^5 + Rs.\ 10 \times 10^5 = Rs.\ 22 \times 10^5$

Total cost = Fixed cost + running cost

$= Rs.\ 70 \times 10^5 + Rs.\ 22 \times 10^5 = Rs.\ 92 \times 10^5$

Cost of energy per kW hr,

$$= \frac{92 \times 10^5}{609.696 \times 10^3}$$

$= Rs.\ 0.151$

$= 15.1$ paise.

5) The following data pertain to a power plant Installed capacity 200= MW; Capital cost= Rs. 350 x 10^7; Annual cost of fuel, taxes and salaries= Rs. 55 x 10; Rate of interest is 5% of the capital; Rate of depreciation is 6% of the capital; Annual load factor = 0.65; Capacity factor= 0.56; Energy used in running the plant auxiliaries = 4% of total units generated. Determine the (a) cost of power generation and (b) reserve capacity.

Solution:

Load factor = $\frac{Average\ Load}{Maximum\ demand}$ **-----------(1)**

Capacity factor = $\frac{Average\ Load}{Plant\ capacity}$ **------------**
(2)

Divided by equation (1) to equation (2)

$$\frac{Load\ factor}{Capacity\ factor} = \frac{Average\ Load}{Maximum\ demand} \times \frac{Plant\ capacity}{Average\ load}$$

$$\frac{0.65}{0.56} = \frac{200}{Maximum\ demand}$$

Maximum demand = 200 x $\frac{0.56}{0.65}$

= **172.3 MW**

Reserve capacity = 200-172.3 = 27.7 MW

From equation (1),

Average load = Load factor x Maximum demand

= 0.65 x 172.3 = 112 MW

Energy produced per year

= 112 x (365 x 24)

= 981120 MW

= 981.12×10^6 kWh

Net energy delivered,

= Energy produced - Energy used in running the plant auxiliaries

$$= 981.12 \times 10^6 - 981.12 \times 10^6 \times \frac{4}{100}$$

= 941.8752×10^6 kWh

Annual interest = $0.05 \times 350 \times 10^7$

= **Rs: 17.5×10^7**

Annual depreciation = $0.06 \times 350 \times 10^7$

= **Rs. 21×10^7**

Fixed cost = Annual interest + Annual depreciation

= $17.5 \times 10^7 + 21 \times 10^7$

= **Rs. 38.5×10^7**

Total annual cost = Fixed cost + Running cost

= $38.5 \times 10^7 + 55 \times 10^7$

= **Rs. 93.5×10^7**

Cost of power generation

$$= \frac{Total\ annual\ cost}{Net\ energy} = \frac{93.5 \times 10^7}{941.8725 \times 10^6}$$

= **Rs. 0.9927**

= **99.27 paisa**

6) A power station supplies the following loads to the customers

Time in hrs	0 – 6	6 – 12	12 – 14	14 – 18	18 – 24
Load in MW	45	120	90	140	70

(a) Draw the load curve and load duration curve.
(b) Calculate the load factor.
(c)Calculate the plant capacity factor and utilization factor of the plant serving this load if its rated capacity is 170 MW

Solution:

(a) The load curve and load duration curve are drawn as shown in Figures

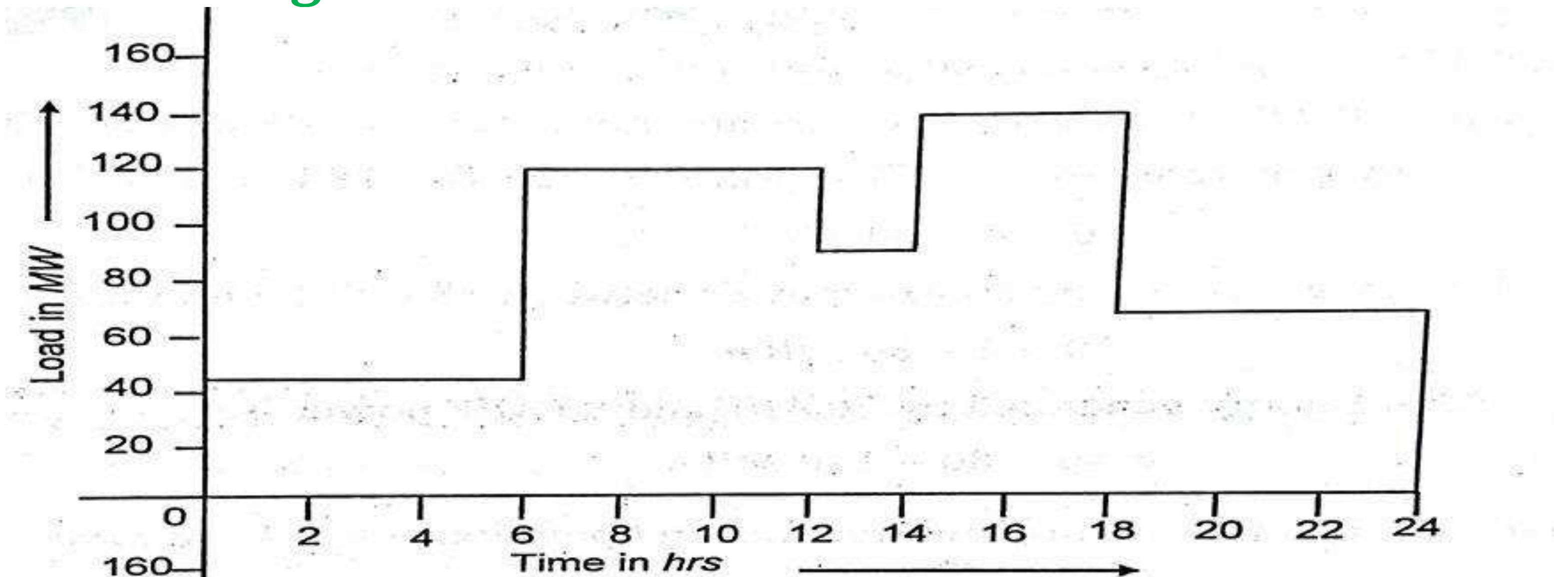
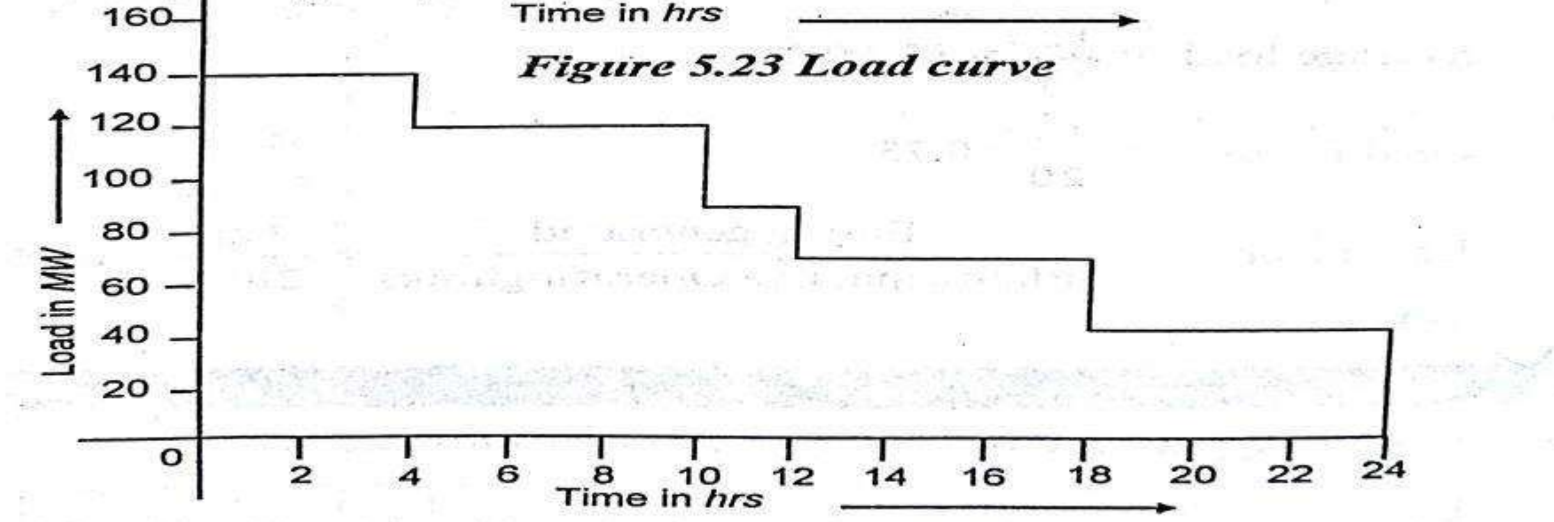


Figure 5.23 Load curve



b) Energy generated Area under load curve

$$= 45 \times 6 + 120 \times 6 + 90 \times 2 + 140 \times 4 + 70 \times 6$$

$$= 2150 \text{ MWh}$$

$$\text{Average Load} = \frac{2150}{24}$$

$$= 89.583 \text{ MW}$$

Maximum demand = **140 MW**

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Maximum demand}}$$

$$= \frac{89.583}{140}$$

$$= 0.64$$

c) Plant capacity factor =

$$= \frac{Energy\ generated}{Capacity\ of\ the\ plant\ x\ Operating\ in\ hrs}$$

$$= \frac{2150}{170\ x\ 24}$$

$$= \mathbf{0.52}$$

Utilization factor $= \frac{Maximum\ Load}{Capacity\ of\ the\ plant}$

$$= \frac{140}{170}$$

$$= \mathbf{0.823}$$

7) The loads on a power plant with respect to 24 hours are listed below.

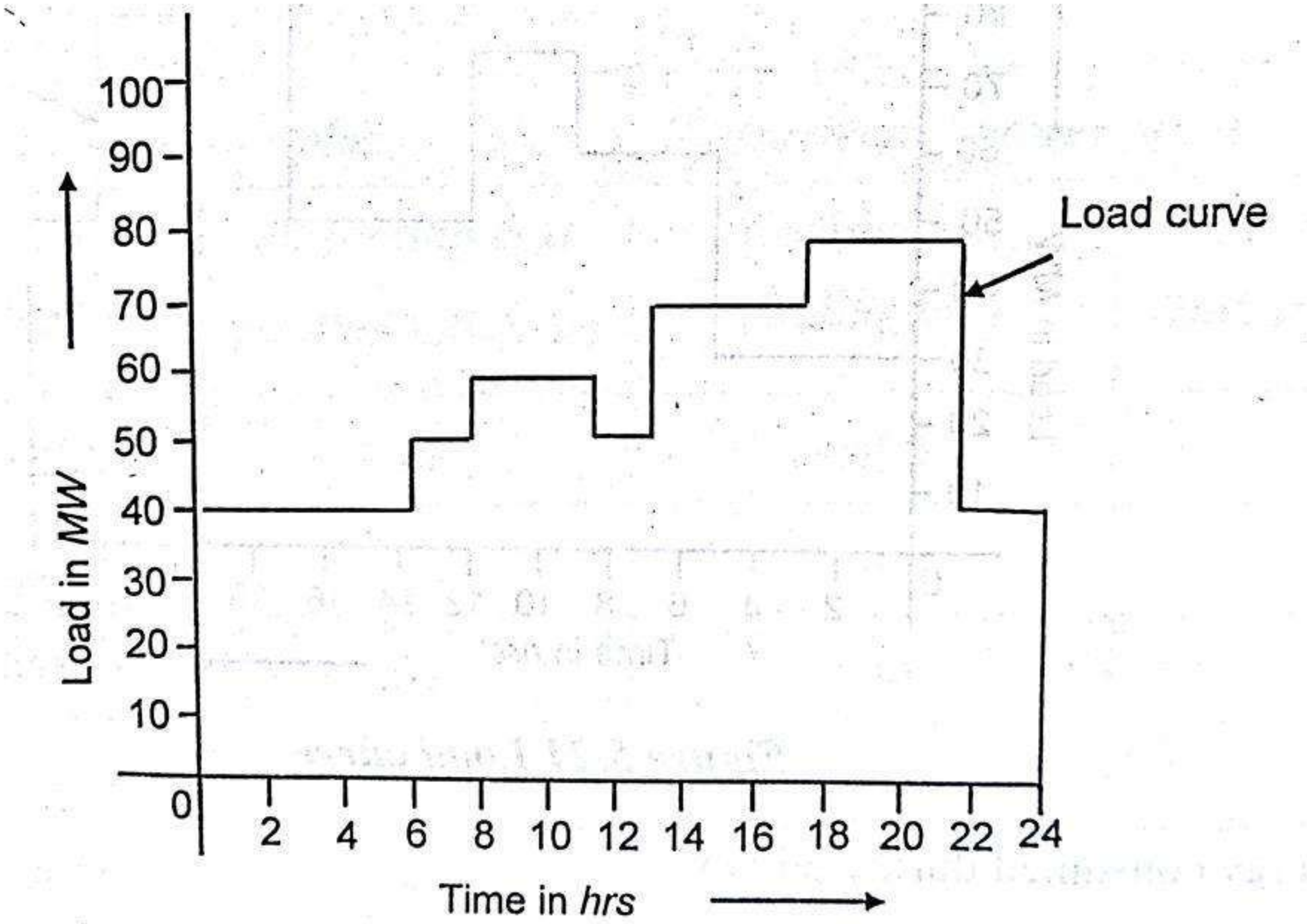
Time in hrs	0 – 6	6 – 8	8 – 12	12 – 14	14 – 18	18 –22	22-24
Load in MW	40	50	60	50	70	80	40

(a)Draw the load curve and find out the load factor of the power station.

(b)If the loads above 60 MW are taken by a standby unit of 20 MW capacity, find the load factor and use factor of the standby unit

Solution:

(a) Based on the data given, the load curve is drawn as shown in Figure



Energy generated area under the load curve

$$= 40x6 + 50x2 + 60x4 + 50x2 + 70x4 + 80x4 + 40x2$$

$$= 1360MWh$$

Average load $= \frac{1360}{24}$

$$= 56.667MW$$

Load factor $= \frac{Average\ Load}{Maximum\ demand}$

$$= \frac{56.667}{80}$$

$$= 0.708$$

(b) If the load above 60 MW is supplied by a standby unit of 20MW capacity, the energy generated by it can be calculated as follows:

Only 70 MW and 80 MW powers are more than 60 MW power. Therefore,

Energy generated by 70 MW power between 14 - 18 hours i.e. 4 hours is

= 10 x4 = 40 MWh

Energy generated by 80 MW power between 18 -22 hours

i.e. 4 hours is

= 20 x 4 = 80 MWh

Total Energy generated by 70 MW and 80 MW power is

= 40+ 80 = 120 MWh

Time during which the standby unit remains in operation

= 4 + 4 = 8hours

Average load $= \dfrac{120}{8}$

$= \mathbf{15\ MW}$

Load factor $= \dfrac{15}{20}$

$= \mathbf{0.75}$

Use factor $= \dfrac{Energy\ generated}{Plant\ capacity\ x\ Operating\ hrs}$

$= \dfrac{120}{20\ x\ 8}$

$= \mathbf{0.75}$

8) A central power station has annual factors as follows, Load factor = 60%; Capacity factor= 40%; Use factor = 45%; Power station has a maximum demand of 15,000 MW. Determine the annual energy production, reserve capacity over and above peak load and hours per not in service.

Solution:

a) Annual energy production

$$\text{Load factor} = \frac{\textit{Average Load}}{\textit{Maximum demand}}$$

$$0.6 = \frac{\textit{Average Load}}{15{,}000}$$

Average Load = 9000 kW

Annual energy production = 9000 x 24 x 365

= 78840000 kW-hr

b) Reserve capacity over and above the peak Load

$$\text{Capacity Factor} = \frac{\text{Average Load}}{\text{Plant Capacity}}$$

$$\text{Plant Capacity} = \frac{9000}{0.4}$$

$$= 22{,}500 \text{ kW}$$

Reserve capacity over of above the peak load

$$= 22{,}000 - 15{,}000$$

$$= 7500 \text{ kW}$$

c) Hour per year not in use (or) service

$$\text{Use Factor} = \frac{\text{Annual energy production in given time period}}{\text{Maximum energy production by the plant}}$$

$$0.45 = \frac{78840000}{22{,}500 \times \text{Hours in operation}}$$

Hours in operation = 7786.67 hrs

Hours not in use in a year = (24 x 365) – 7786.67

= 973.33 hrs