JES, JHARSUGUDA

POWER STATION ENGINEERING

(LECTURE NOTES)

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TH.3 POWER STATION ENGINEERING

Name of the Course: Diploma in MECHANICAL ENGINEERING			
Course code:		Semester	6th
Total Period:	60	Examination	3 hrs
Theory periods:	4 P/W	Internal assessment	20
Maximum marks:	100	End Semester Examination:	80

A. RATIONALE:

Bulk powers used in industries and for domestic purposes are generated in power stations. A large number of diverse and specialized equipment and system are used in a power plant should have this important subject in mechanical engineering.

B. COURSE OBJECTIVES:

At the end of the course the students will be able to:

- Understand the generation of power by utilizing various energy sources.
- Understand the use of steam, its operation in thermal power stations.
- Understand the nuclear energy sources and power developed in nuclear power station.
- Understand the basics of diesel electric power station and hydroelectric power station.
- Understand the basics of gas turbine power station
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C.TOPIC WISE DISTRIBUTION OF PERIODS

Sl No.	Topic	Periods
1	**INTRODUCTION**	05
2	**THERMAL POWER STATIONS**	20
3	**NUCLEAR POWER STATIONS**	10
4	**DIESEL ELECTRIC POWER STATIONS**	10
5	HYDEL POWER STATIONS	10
6	GAS TURBINE POWER STATIONS	05

D.COURSE CONTENTS:

1.0 INTRODUCTION:

1.1 Describe sources of energy.
1.2 Explain concept of Central and Captive power station.
1.3 Classify power plants.
1.4 Importance of electrical power in day today life.
1.5 Overview of method of electrical power generation.

2.0 THERMAL POWER STATIONS:

2.1 Layout of steam power stations.

2.2 Steam power cycle. Explain Carnot vapour power cycle with P-V, T-s diagram and determine thermal efficiency.

2.3 Explain Rankine cycle with P-V, T-S & H-s diagram and determine thermal efficiency, Work done, work ratio, and specific steam Consumption.

2.4 Solve Simple Problems.

2.5. List of thermal power stations in the state with their capacities.

2.6 Boiler Accessories: Operation of Air pre heater, Operation of Economiser, Operation Electrostatic precipitator and Operation of super heater. Need of boiler mountings and operation of boiler

2.7 Draught systems (Natural draught, Forced draught & balanced draught) with their advantages & disadvantages.
2.8 Steam prime movers: Advantages & disadvantages of steam turbine, Elements of steam turbine, governing of steam turbine. Performance of steam turbine: Explain Thermal efficiency, Stage efficiency and Gross efficiency.
2.9 Steam condenser: Function of condenser, Classification of condenser. function of condenser auxiliaries such as hot well, condenser extraction pump, air extraction pump, and circulating pump.
2.10 Cooling Tower: Function and types of cooling tower, and spray ponds
2.11 Selection of site for thermal power stations.

3.0 NUCLEAR POWER STATIONS:

3.1 Classify nuclear fuel (Fissile & fertile material)
3.2 Explain fusion and fission reaction.
3.3 Explain working of nuclear power plants with block diagram .
3.4 Explain the working and construction of nuclear reactor .
3.5 Compare the nuclear and thermal plants.
3.6 Explain the disposal of nuclear waste.
3.7 Selection of site for nuclear power stations.
3.8 List of nuclear power stations.

4.0 DIESEL ELECTRIC POWER STATIONS:

4.1 State the advantages and disadvantages of diesel electric power stations.
4.2 Explain briefly different systems of diesel electric power stations: Fuel storage and fuel supply system, Fuel injection system, Air supply system, Exhaust system, cooling system, Lubrication system, starting system, governing system.
4.3 Selection of site for diesel electric power stations.
4.4 Performance and thermal efficiency of diesel electric power stations.

5.0 HYDEL POWER STATIONS:

5.1 State advantages and disadvantages of hydroelectric power plant.
5.2 Classify and explain the general arrangement of storage type hydroelectric project and explain its operation.
5.3 Selection of site of hydel power plant.
5.4 List of hydro power stations with their capacities and number of units in the state.
5.5 Types of turbines and generation used.
5.6 Simple problems.

6.0 GAS TURBINE POWER STATIONS

6.1 Selection of site for gas turbine stations.
6.2 Fuels for gas turbine
6.3 Elements of simple gas turbine power plants
6.4 Merits, demerits and application of gas turbine power plants.

Syllabus covered up to I.A-Chapters 1,2 &3

INTRODUCTION

ENERGY- It is the ability possessed by a body to produce a dynamic, vital effect. Energy is associated with a physical substance, but not a substance itself.

POWER- Power is primarily associated with mechanical work and electrical energy. Therefore, power can be defined as the rate of flow of energy and can state that a power plant is a unit built for production and delivery of a flow of mechanical and electrical energy.

SOURCES OF ENERGY

The various sources of energy are :

1. Fuels	**Solids—Coal, coke anthracite etc.** **Liquids—Petroleum and its derivatives** **Gases—Natural gas, blast furnace gas etc.**	**Conventional**
2. Energy stored in water **3. Nuclear energy** **4. Wind power** **5. Solar energy** **6. Tidal power** **7. Geothermal energy** **8. Thermoelectric power.**		**Non-conventional**

1.2 Source of Energy

The various sources of energy are as follows:
1. **Fuels.** The fuels are broadly classified as follows
(i)Solid fuels: Various solid fuels used are wood, coal including bituminous coal, anthracite, lignite, peat, etc.
(ii)Liquid fuels: Liquid fuels include petroleum and its derivatives.
(iii)Gaseous fuels: Gaseous fuels consist of natural gas, producer gas, blast furnace gas, coal gas etc.

2**. Energy Stored in Water**. The potential energy of water at higher level is utilized for the generation of electrical energy. Water power is quite cheap where water is available in abundance. Although capital cost of hydroelectric power plants is higher as compared to other types of power plants but their operating costs are quite low.

3. **Nuclear Energy.** Controlled fission of heavier unstable atoms such as U^{235} **,** Th^{232} and artificial elements Pu^{239} liberate large amount of heat energy. This enormous release of energy from a relatively small mass of nuclear fuels makes this source of energy of great interest. Nuclear power can cater to the future needs of energy. Three stages of Indian nuclear power programme are as follows
(i) natural uranium fuelled pressurised heavy water reactors.
(ii) fast breeder reactors utilising plutonium based fuel.
(iii) advanced nuclear power systems for utilisation of thorium.

4. **Wind Power**-Wind energy is a renewable source of energy. The wind power systems are non-polluting. However wind energy is noisy in operation and large area is required to install wind mills. Wind energy is weak and fluctuating in nature. In India, wind velocity along coast line has a range of 10-16 kmph and a survey of wind power has revealed that wind power used to pump water from deepwells or for generating electric energy in smaller amount. Modern wind mills are capable of working on velocities as low as 3-7 kmph velocity while maximum efficiency is attained at a velocity ranging between 10-12 kmph.

5**. Solar Energy.** The heat energy contained in the rays of sun is utilised to boil water and generate steam which call used to drive prime movers to generate electrical energy. carrying out a co-ordinated programme of research in solar energy.
Some of the fields in which solar energy can be used are as follows:
(i) Solar power plants used for electric power generation
(ii) Solar water pumps used for pumping water.
(iii) Solar water heaters used *for* water heating.
(iv) Solar cabinet type driers for drying of food grains.
(v) Solar kilns for drying wood etc.
Solar energy is effective, only during day time and if power supply is to be made during night also then some reservoir of energy such as storage battery or heat accumulator should be used. Solar energy cannot be used during cloudy weather and rainy season, if solar energy is used efficiently there would be enough power to meet the increasing power demand for several years to come. etc.). It is believed that solar power can become economically feasible with the following aims achieved:
1. Availability of better heat Collectors.
2. Availability of improved materials and manufacturing techniques.
3. Better techniques for storage and cheap distribution of solar power.

6. **Tidal Power**. Ocean waves and tides contain large amount of energy. Such tides rise and fall and water can be stored during rise period and it can be discharged during fall.

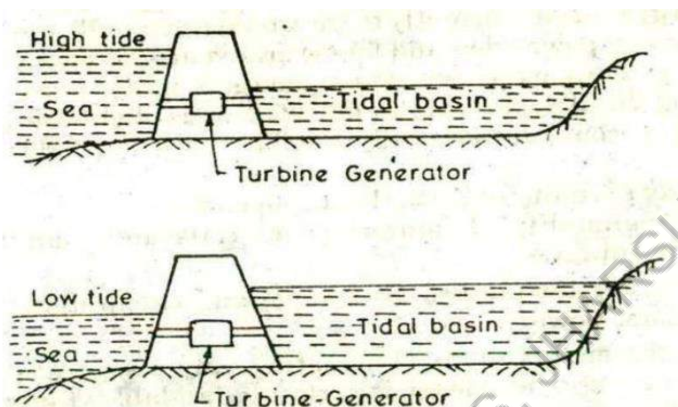
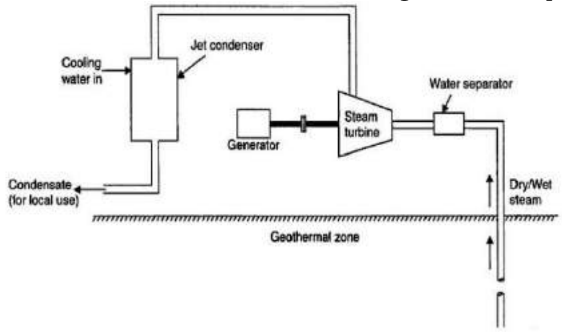


Fig. 1.1.

In India the possible sites, identified for tidal power plants are as follows
(i) Gulf of Cambay
(ii) Gulf of Kutch
(iii) Sunderban area in West Bengal.
The tidal range in the Gulf of Cambay is about 10.8 metre. Whereas the maximum range in Gulf ofKutch is *7.5* metre. The tidal range in Sunderban area is 4.3 metre.
Advantages:
The various advantages of tidal power plants are as follows:
- The power generated does not depend on rain. Therefore there is certainty of power supply as the tidal cycle is very definite.
- The tidal power plants are free from pollution.
- Unhealthy wastes like ash, gases etc. are not produced.
- These plants require lesser space.
- Such plants have a unique capacity to meet the peak power demand effectively when they work in combination with hydro power plants and steam power plants

Disadvantages:
The various disadvantages of tidal power plants are as follows:
- The capital cost of tidal power plant (nearly Rs. 5000 per kW) is .considerably large as compared to steam powerplant and hydro power plant.
- The supply of power is not continuous as it depends upon the timing of tides.
- Tidal power plants are located away from load centres.
- This increases power transportation cost.

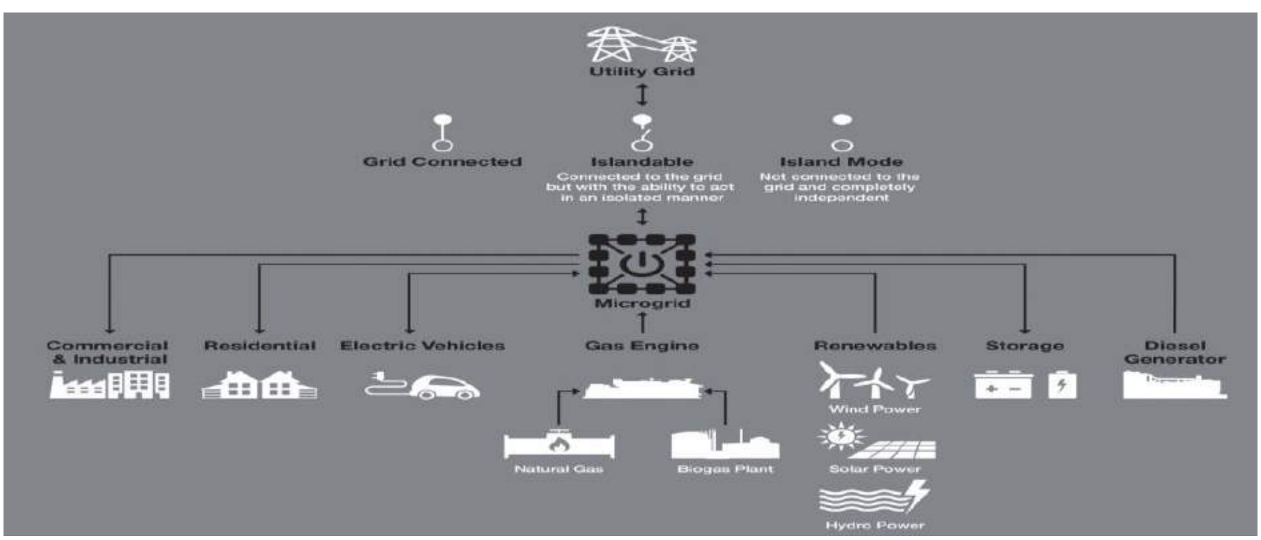
7. **Geothermal Energy**. According to various theories the earth has a molten core. The fact that volcanic action takes place in many places on the surface of earth supports these theories. The steam vents and hot springs come out of earth's surface. The steam from such natural steam wells is used for the generation of power.



8. **Thermo-electric Plant**. When the two junctions of loop of two dissimilar metals are kept at different temperatures, an electromotive force is developed and current starts flowing in the loop. This is known as Seebeck effect. By using suitable materialsthis method call be used for the generation of electrical energy in small amounts.

1.2.1. Conventional and Non-conventional sources of energy.
The sources of energy used for mass generation of power called conventional sources ofénergy are as follows
(i) Thermal *(ii)* Hydro-power *(iii)* Nuclear power.
The non-conventional sources of energy used for generating power in lesser magnitude are as follows
(i) Solar energy *(ii)* Wind power*(iii)* Tidal power *(iv)* Bio-gas(v) Magneto-Hydro-dynamic plant
(vi) Geo-thermal energy.

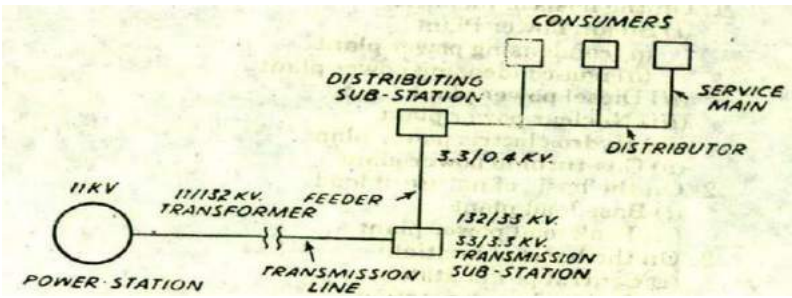
CONCEPT OF CENTRAL AND CAPTIVE POWER STATION
A **captive power plant** is a facility that provides a localised source of power to an energy user. These are typically industrial facilities, large offices or data centres. The plants may operate in grid parallel mode with the ability to export surplus power to the local electricity distribution network. Alternatively they may have the ability to operate in island mode; i.e. independently of the local electricity distribution system.
Captive Power Plants: An electricity generation system, which is used by an industrial or commercial energy consumer for its own energy consumption, is a captive power plant, which is also known as auto-producers or built-in production. Captive power plants can operate outside the grid or link to the grid to exchange surplus energy.
In general, power-intensive industries use captive power plants, in order to maintain stability and supply efficiency, such as aluminum casting, stainless steel, chemical, etc. Radical declines in the costs of solar systems have allowed less energy intensive industries to experience economic grid defects by combining solar photovoltaics with generators or cogeneration units with battery systems.



Benefits of captive power plants

- Security of power supply and resilience through self-generation
- Reduced costs through high fuel efficiency, particularly when in CHP configuration
- Improved environmental performance resulting from fuel efficiency

Centralised Power station: Centralized generation "refers to large-scale power generation in centralized plants. These systems are generally located outside end-users and connected to a high-voltage transmission network.
Central power station is referred to as large-scale power generation in centrally located plants. Generally located outside end-users, these systems are connected to a high voltage transmission network.
Centralized generation facilities include fossil-fuel-fired power plants, nuclear power plants, hydroelectric dams, wind farms, and more.



Types of Power Plants

Based upon the various factors the power plants are classified as follows

1. On the basis of fuel used
   (i) Steam Power Plant
      (a) condensing power plant
      (b) non-condensing power plant
   (ii) Diesel power plant
   (iii) Nuclear power plant
   (iv) Hydro electric power plant
   (v) Gas-turbine power plant
2. On the basis of nature of load
   (i) Base load plant
   (ii) Peak load power plant
3. On the basis of location
   (i) Central power station
   (ii) jolted power station
4. On the lasis of service rendered.
   (i) Stationary
   (ii) Locomotive.

IMPORTANCE OF ELECTRICAL POWER IN DAY TO DAY LIFE

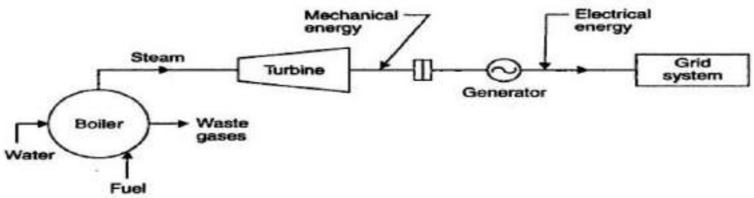
Electricity has many uses in our day to day life. It is used for lighting rooms, working fans and domestic appliances like using electric stoves, A/C and more. All these provide comfort to people. In factories, large machines are worked with the help of electricity. Essential items like food, cloth, paper and many other things are the product of electricity.
Modern means of transportation and communication have been revolutionised by it. Electric trains and battery cars are quick means of travel. Electricity also provides means of amusement, radio, television and cinema, which are the most popular forms of entertainment are the result of electricity. Modern equipment like computers and robots have also been developed because of electricity. Electricity plays a pivotal role in the fields of medicines and surgery too — such as X-ray, ECG. The use of electricity is increasing day by day because it's a highly flexible, easily transmitted, compact, convenient and clean form of energy.

OVERVIEW OF METHOD OF ELECTRICAL POWER GENERATION

There are various methods of electricity generation dependent on types of energy.
Among resource energies, coal and natural gas are used to generate electricity by combustion (thermal power), Uranium by nuclear fission (nuclear power), to utilize their heat for boiling water and rotating steam turbine.
Among renewable energies, sunlight is directly converted into electricity (photovoltaics), rotation energy by wind is converted into electricity (wind power), rotating water wheel by running water to generate(hydro). Magmatic heat boils underground water to rotate steam turbine to generate (geothermal).
Continuous technology development for them are proceeding to convert resource energies or renewable energies into electricity with less loss. It is also important for the operation of power plant to do maintenance or training of operators.

THERMAL POWER STATION

A steam power plant *converts the chemical energy of the fossil fuels (coal, oil, gas) into mechanical / electrical energy.* This is achieved by raising the steam in the boilers, expanding it through the turbines and coupling the turbines to the generators which convert mechanical energy to electrical



Production of electrical energy by steam power plant

LAYOUT OF A MODERN STEAM POWER PLANT

It comprises of four circuits

1. Coal and ash circuit.
2. Air and gas circuit.
3. Feed water and steam flow circuit.
4. Cooling water circuit.

The brief descripation of these circuits is given below :

1. **Coal and ash circuit.** Coal arrives at the storage yard and after necessary handling, passes on to the furnaces through the *fuel feeding device.* Ash resulting from combustion of coal collects at the back of the boiler and is removed to the ash storage yard through *ash handling equipment.*

2. **Air and gas circuit.** Air is taken in from atmosphere through the action of a forced or induced draught fan and passes on to the furnace through the *air preheater*, where it has been heated by the heat of flue gases which pass to the chimney *via* the preheater. The flue gases after passing around boiler tubes and superheater tubes in the furnace pass through a *dust* catching device or precipitator, then through the economiser, and finally through the air preheater before being exhausted to the atmosphere.

3. **Feed water and steam flow circuit.** In the water and steam circuit condensate leaving the condenser is first heated in a closed feed water heater through extracted steam from the lowest pressure extraction point of the turbine. It then passes through the *deaerator* and a few more water heaters before going into the boiler through *economiser.*

In the boiler drum and tubes, water circulates due to the difference between the density of water in the lower temperature and the higher temperature sections of the boiler. Wet steam from the drum is further heated up in the superheater before being supplied to the primemover. After expanding in high pressure turbine steam is taken to the reheat boiler and brought to its original dryness or superheat before being passed on to the low pressure turbine. From there it is exhausted through the condenser into the hot well. The condensate is heated in the feed heaters using the steam trapped (bled steam) from different points of turbine.

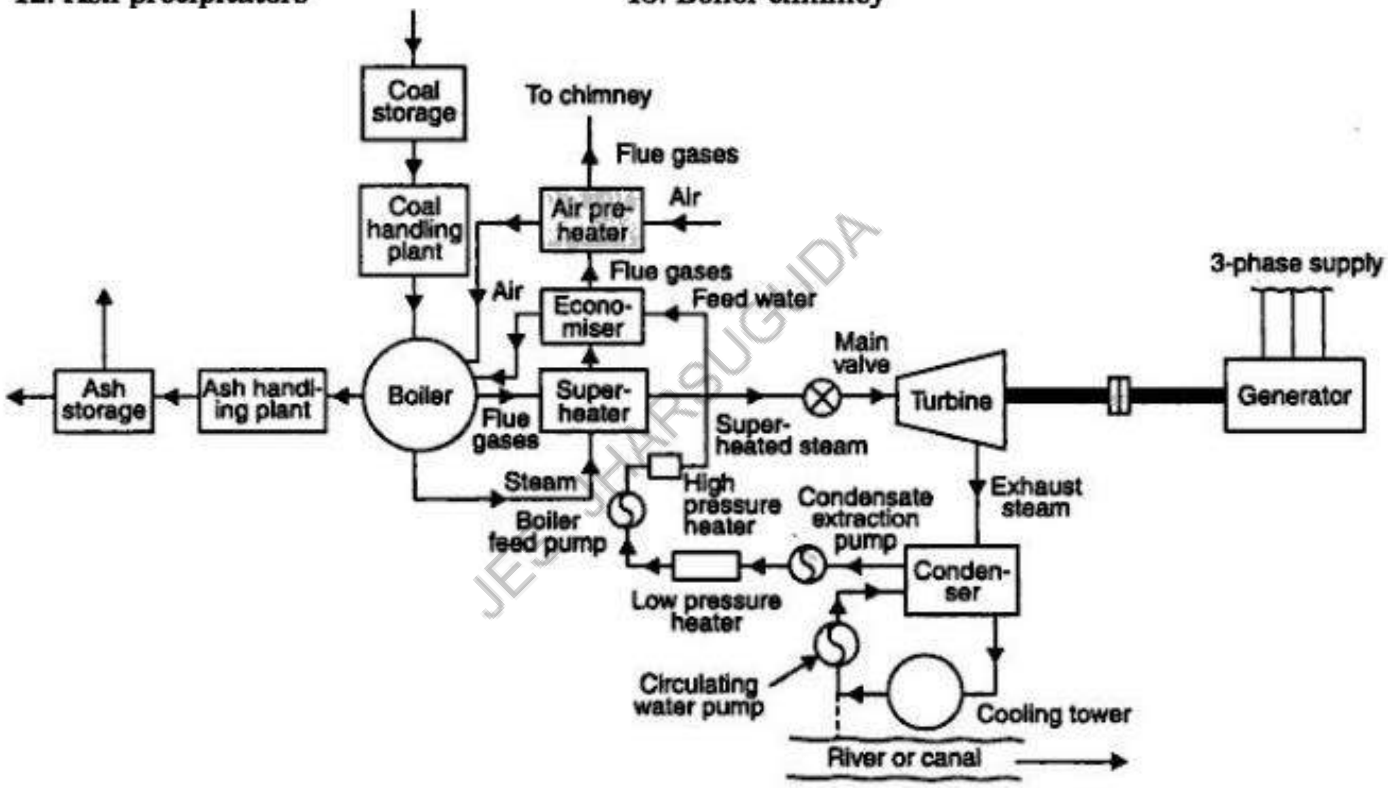
A part of steam and water is lost while passing through different components and this is compensated by supplying additional feed water. This feed water should be purified before hand, to avoid the scaling of the tubes of the boiler.

4. **Cooling water circuit.** The cooling water supply to the condenser helps in maintaining a low pressure in it. The water may be taken from a natural source such as river, lake or sea or the same water may be cooled and circulated over again. In the later case the cooling arrangement is made through spray pond or cooling tower.

Components of a Modern Steam Power Plant :

A modern steam power plant consists of the following *components :*

1. Boiler
   (*i*) Superheater
   (*ii*) Reheater
   (*iii*) Economiser
   (*iv*) Air-heater
2. Steam turbine
3. Generator
4. Condenser
5. Cooling towers
6. Circulating water pump
7. Boiler feed pump
8. Wagon tippler
9. Crusher house
10. Coal mill
11. Induced draught fans
12. Ash precipitators
13. Boiler chimney



LAYOUT OF A STEAM POWERPLANT

CLASSIFICATION OF POWER PLANT CYCLES:

They are generally classified into

- Vapour Power cycles
  1.Rankine cycles 2.Reheat cycle 3.Regenerative cycle 4.Binary vapour cycle
- Gas Power cycles
  1.Otto cycle 2. Diesel cycle 3.Dual combustion cycle 4.Gas turbine cycle
  a)open cycle b)closed cycle

CARNOT CYCLE:

It consists of (i)2 constant pressure operations (4-1) and (2-3) and (ii)2 frictionless adiabatics (1-2) and (3-4).These operations are:

1. Operation(4-1): 1kg of boiling water at temperature T_1 is heated to form wet steam of dryness fraction x_1.Thus heat is absorbed at constant temperature T_1 and pressure p_1 during this operation.
2. Operation(1-2):During this operation steam is expanded isentropically to temperature T_2 and pressure p_2. The point '2' represents the condition of steam after expansion.

3. Operation(2-3):During this operation heat is rejected at a constant pressure p_2 and temperature T_2. As the steam is exhausted it becomes wetter and cooled from 2 to3.
4. Operation(3-4): In this operation the wet steam at '3' is compressed isentropically till the steam regains its original state of temperature T_1 and pressure p_1. Thus cycle is completed.

   Refer to T~s diagram:

   Heat supplied at constant temperature T_1(operation(4-1))= Area 4-1-b-a= $T_1(s_1-s_4)$ or $T_1(s_2-s_3)$

   Heat rejected at constant temperature T_2(operation(2-3))= Area 2-3-a-b= $T_2(s_2-s_3)$

   Since there is no exchange of heat during isentropic operations (1-2) and (3-4), therefore,

   Net work done = Heat supplied-heat rejected

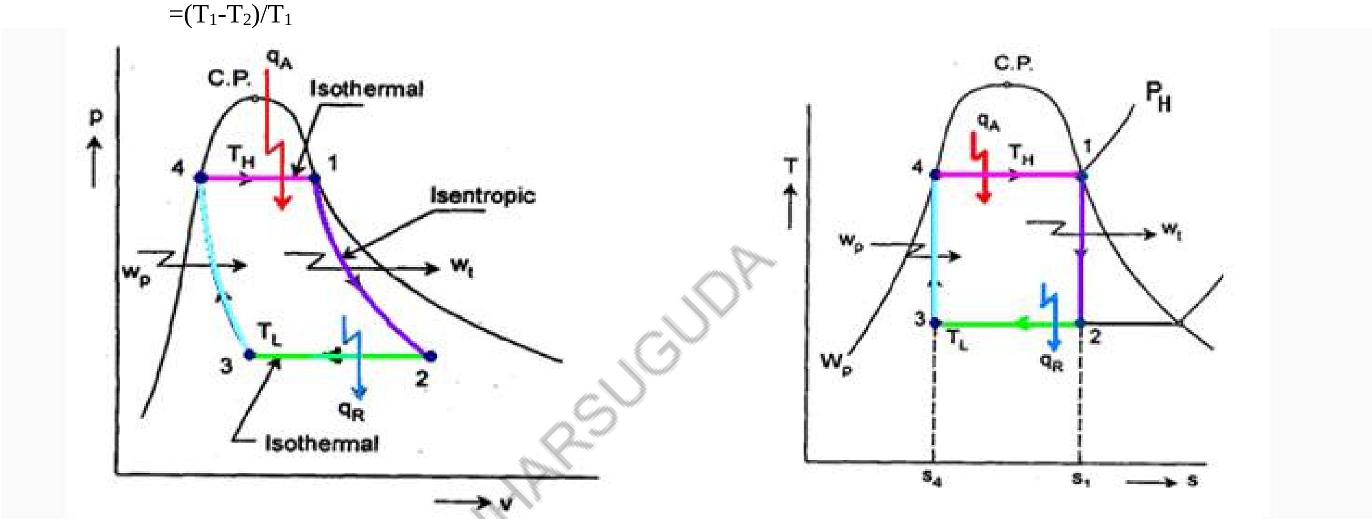
   $=T_1(s_2-s_3)- T_2(s_2-s_3)$

   $=(T_I-T_2)(s_2-s_3)$

   Carnot cycle,$\eta = \frac{work\ done}{heat\ supplied}$

   $=(T_I-T_2)(s_2-s_3))/T_2(s_2-s_3)$

   $=(T_1-T_2)/T_1$



P~V and T~s diagram for carnot cycle

<u>LIMITATIONS OF CARNOT CYCLE</u>:

Carnot vapour power cycle is an ideal cycle, efficiency of which is independent of the working substance

$$\left(\eta_{Carnot} = 1 - \frac{T_2}{T_1}\right).$$

But it is extremely difficult to operate in practice because of the following reasons :

(a) It is difficult to compress a wet vapour isentroprically to the saturated state as required by the process (4-1).

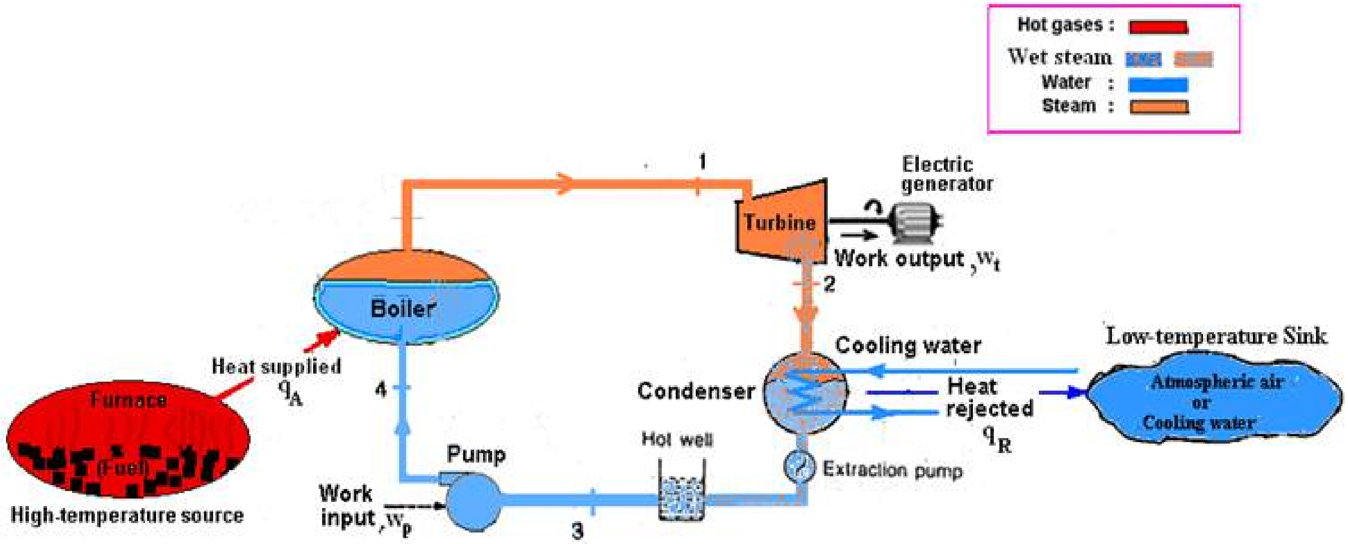
(b) It is difficult to control the quality of the condensate coming out of the condenser so that the state '4' is exactly obtained.

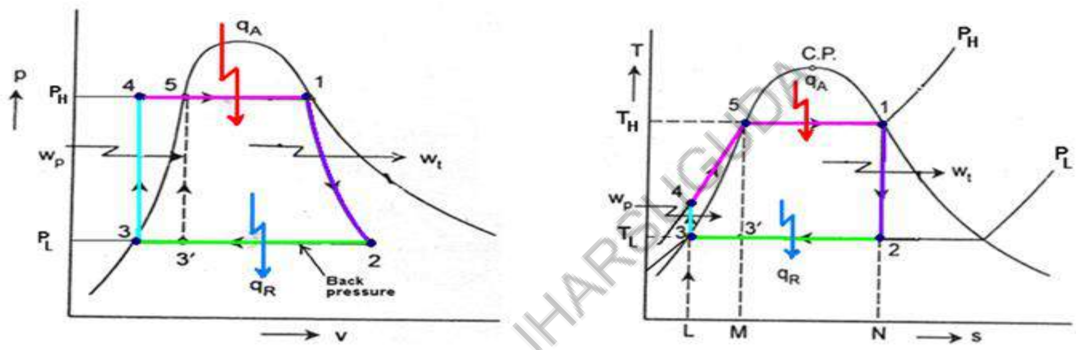
(c) The efficiency of the Carnot cycle is correctly attached by the temperature T_1 at which heat is transferred to the working fluid. Since the temperature of steam is only 374ºC, therefore, if the cycle is to be operated in the wet region, the maximum possible temperature is severely limited.

(d) Due to the above reasons, it is not possible to achieve the high efficiency as derived the Carnot vapour cycle. Isentropic compression of a vapour requires more work due to its high specific volume thereby reducing the work ratio.

(e) Isothermal heat addition after the saturated vapour line is very difficult to achieve as it involves heat addition at the same time expansion of steam.

RANKINE CYCLE:





Rankine cycle on p-v and T-s diagrams

(i) Boiler: In boiler the working fluid (water) at state '4' in sub cooled condition is converted into dry saturated steam at state '1' by receiving heat 'q_A' from combustion of fuel (high temperature heat source) through the following processes.

Process 4-5: As thewater enters the boiler from pump in sub cooled condition state '4' at pressure P_H, it is first heated up to the saturated state 5 at constant pressure (sensible heating).

Process 5-1: Then water at saturated condition 5 is further heated up at constant pressure P_H and constant saturation temperature to the saturated steam at state 1 (latent heat of vaporization).

Process 4-5-1: Total heat addition in boiler,

$q_A = {}_4q_1 = h_{g,1} - h_{sub,4}$ since ${}_4w_1 = 0$ (from 1st law of thermodynamics for flow process)

(ii) Steam Turbine: In the steam turbine, the dry saturated steam from the boiler at state '1' at pressure 'p_H' expands isentropically to state '2' (wet steam) at pressure 'p_L' and thus produce mechanical work, w_t.

Process 1-2: Isentropic expansion of steam in turbine (Steam turbine work, w_t)

${}_1q_2 = 0$ (as the process is adiabatic)

Steam turbine work is given by,

$w_t = {}_1w_2 = h_{g,1} - h_2$ (from 1st law of thermodynamics for flow process)

(iii) Condenser: In the condenser, the exhaust wet steam from turbine at state '2' is condensed by rejecting heat 'q_R' to the cooling water.

Process 2-3: Constant pressure (back pressure), constant temperature heat rejection in condenser (Condensation)

Total heat rejected in condenser,

$q_R = {}_2q_3 = h_2 - h_{f,3}$ since ${}_2w_3 = 0$ (from 1st law of thermodynamics for flow process)

(iv) Feed pump: The feed pump is used to pump the condensate at state '3' (saturated water) from the hot-well to the boiler at the boiler pressure, p_H.

Process 3-4: Isentropic compression of water in pump (Pump work, wp)

${}_3q_4 = 0$ (as the process is adiabatic)

Rankine cycle efficiency of a good steam power plant may be in the range of 35% to 45%.

Rankine cycle neglecting pump work

In a Rankine cycle the pump work may be neglected as it is very small compared with other energy transfers. Hence we have

$w_p = 0$

As shown in Figure 31.6 neglecting the pump work $(p_4'-p_3')v_{f,3}'$ denoted by area 44'3'3 in the p-v diagram for the Rankine cycle will be presented by 1234.

Total heat addition in boiler in process 3-1 is given by,

$q_A = {}_3q_1 = h_{g,1} - h_{f,3}$ since ${}_3w_1 = 0$ (from 1st law of thermodynamics for flow process)

Total heat rejected in condenser,

$q_R = {}_2q_3 = h_2 - h_{f,3}$ since ${}_2w_3 = 0$ (from 1st law of thermodynamics for flow process)

Net work done during cycle, w_{net} = Heat added (q_A) – heat rejected (q_R)

$= (h_{g,1} - h_{f,3}) - (h_2 - h_{f,3})$

$= (h_{g,1} - h_2)$

Therefore, Thermal efficiency =

$$(\eta_{th}) = \frac{\text{Net work done during cycle}}{\text{Heat added}} = \frac{w_{net}}{q_A} = \frac{(h_{g,1} - h_2)}{(h_{g,1} - h_{f,3})}$$

WORK RATIO – It is defined as the ratio of net work output to the work produced by turbine (positive work).

W.R $= W_{net}$/+ve work $= (W_T - W_P)/W_T$

$(W.R)_{Rankine} > (W.R)_{Carnot}$

Similarly, Back work ratio, B.W.R= -ve work/+ve work $= W_P/W_T$

$(B.W.R)_{Rankine} < (B.W.R)_{Carnot}$ (since, -ve work(pump work) is very less as compared to +ve work in rankine cycle.

SPECIFIC STEAM CONSUMPTION:

This is the parameter which decides the size of plant.

It is the ratio of mass flow rate to produce unit power output.

s.s.c $= \dot{m}_s/(P\ o/p) = \dot{m}_s/(\dot{m}_s * W_{net})$

$= 1/W_{net}$ in kg/kWs

$= 3600/W_{net}$ in kg/kWhr

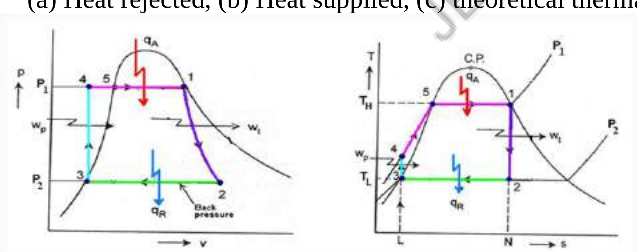
$(W_{net})_{rankine} > (W_{net})_{carnot}$

$(s.s.c)_{rankine} < (s.s.c)_{carnot}$

PROBLEMS

1. Dry and saturated steam at pressure 11 bar is supplied to a turbine and expanded isentropically to pressure 0.07 bar. Calculate the following

(a) Heat rejected, (b) Heat supplied, (c) theoretical thermal efficiency.



Given: Dry and saturated steam supplied to a turbine at pressure, p_1 = 11 bar

Steam expanded isentropically to pressure, p_2 = 0.07 bar.

From Steam table (Dry saturated steam)

At pressure, p_1 = 11 bar → $h_{g,1}$= 2779.7 kJ/kg, $s_{g,1}$ = 6.550 kJ/kg K

At pressure, p_2= 0.07 bar → $h_{f,3}$ = 163 kJ/kg, h_{fg} = 2409.2 kJ/kg, $s_{f,3}$ = 0.559 kJ/kgK,

s_{fg} = 7.718 kJ/kgK, $v_{f,3}$ = 0.001 m^3/kg

(a) Determine heat rejected, q_R

Formula: Heat rejected, $q_R = h_2 - h_{f,3}$

Finding unknown, h_2:

Isentropically expansion, therefore $s_2 = s_{g,1}$

$= 6.554$

Since for wet steam at point '2', $s_2 = s_{f,3} + x_2\ s_{fg,(p=0.07\ bar)}$

Therefore, $s_{f,3} + x_2\ s_{fg,(p=0.07\ bar)} = 6.554$

$0.559 + x_2 (7.718) = 6.550$

$x_2 = 0.776$

Enthalpy for wet steam at point '2', $h_2 = h_{f,3} + x_2 h_{fg,(p=0.07\ bar)}$

$h_2 = 163.4 + 0.776 (2409.2) = 2032.9$ kJ/kg

Answer: Heat rejected, $q_R = h_2 - h_{f,3} = 2032.9 - 163 = 1869.9$ kJ/kg

(b) Determine heat supplied, q_A

Formula: Work done during cycle (w) = Heat supplied (q_A) – heat rejected (q_R)

or $q_A = w + q_R$

Finding unknown, w:

Net work done during cycle, $w = w_t - w_p$

Finding unknown, w_t and w_p :

Turbine work, $w_t = h_{g,1} - h_2 = 2779.7 - 2032.9 = 746.8$ kJ/kg

Pump work, $w_p = v_{f,3} (p_1 - p_2) 10^2 = 0.001 (11 - 0.07) 10^2 = 1.093$ kJ/kg

$w = w_t - w_p = 746.8 - 1.093 = 745.7$ kJ/kg

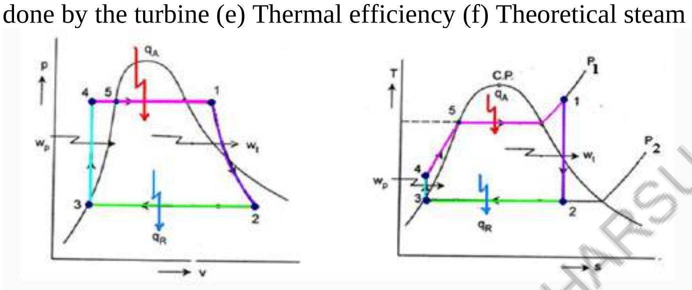
Answer: $q_A = w + q_R = 745.7 + 1869.9 = 2615.6$ kJ/kg

(c) Determine theoretical thermal efficiency η_{th} $= \frac{\text{Work done during cycle}}{\text{Heat supplied}} \times 100 = \frac{745.7}{2615.6} \times 100$

Answer: = 28.5%

2: A steam turbine receives steam at pressure 20 bar and superheated to 88.6°C. The exhaust pressure is 0.07 bar and the expansion of steam takes place isentropically Using steam table, calculate the following.

(a) Heat rejected (b) Heat supplied, assuming that the feed pump supplies water to the boiler at 20 bar (c) Net work done (d) Work done by the turbine (e) Thermal efficiency (f) Theoretical steam consumption.



Given: Superheated steam supplied to a turbine at pressure, $p_1 = 20$ bar

Temperature of superheated steam = $t_{s,1} + 88.6$°C.

From Steam table (Dry saturated steam)

At pressure, $p_1 = 20$ bar $\rightarrow$ $t_{s,1} = 212.4$°C

Therefore, temperature of superheated steam, $t_{sup,1} = 212.4 + 88.6 = 300$°C

From Steam table (superheated steam)

At pressure, $p_1 = 20$ bar and $t_{sup,1} = 300$°C $\rightarrow$ $h_{sup,1} = 3025$ kJ/kg, $s_{sup,1} = 6.768$ kJ/kg

Given: Steam expanded isentropically to pressure, $p_2 = 0.07$ bar.

From Steam table (Dry saturated steam)

At pressure, $p_2 = 0.07$ bar $\rightarrow$ $h_{f,3} = 163$ kJ/kg, $h_{fg} = 2409.2$ kJ/kg, $s_{f,3} = 0.552$ kJ/kgK, $s_{fg} = 7.722$ kJ/kgK, $v_{f,3} = 0.001$ m^3/kg

From Steam table (Dry saturated steam)

At pressure, $p_2 = 0.07$ bar $\rightarrow$ $h_{f,3} = 163$ kJ/kg, $h_{fg} = 2409.2$ kJ/kg, $s_{f,3} = 0.552$ kJ/kgK, $s_{fg} = 7.722$ kJ/kgK, $v_{f,3} = 0.001$ m^3/kg

(a) Determine heat rejected, q_R

Formula: Heat rejected, $q_R = h_2 - h_{f,3}$

Finding unknown, h_2:

Isentropically expansion, therefore $s_2 = s_{sup,1}$

$= 6.768$

Since for wet steam at point '2', $s_2 = s_{f,3} + x_2\ s_{fg,(p=0.07\ bar)}$

Therefore, $s_{f,3} + x_2\ s_{fg,(p=0.07\ bar)} = 6.768$

$0.552 + x_2 (7.722) = 6.768$

$x_2 = 0.8047$

Enthalpy for wet steam at point '2', $h_2 = h_{f,3} + x_2 h_{fg,(p=0.07\ bar)}$

$\mathbf{h_2} = 163.4 + 0.8047 (2409.2) =$ **2101.52 kJ/kg**

Answer: Heat rejected, $\mathbf{q_R} = h_2 - h_{f,3} = 2101.52 - 163 =$ **1938.52 kJ/kg**

(d) Determined work done by the turbine, w_t :

Formula: Turbine work, $w_t = h_{sup,1} - h_2$

Answer: Turbine work, $\mathbf{w_t} = h_{sup,1} - h_2 = 3025 - 2101.52 =$ **923.48 kJ/kg**

(c) Determine net work done, w :

Formula: Net work done during cycle, $w = w_t - w_p$

Finding unknown, w_p :

Pump work, $\mathbf{w_p} = v_{f,3}\,(p_1 - p_2)\,10^2$

$= 0.001\,(20 - 0.07)\,10^2 =$ **1.993 kJ/kg**

Answer: Net work done during cycle, $\mathbf{w} = w_t - w_p$

$= [923.48 - 1.993] =$ **921.487 kJ/kg**

(b) Determine heat supplied, q_A :

Formula: Net work done during cycle (w) = Heat supplied (q_A) – heat rejected (q_R)

or $q_A = w + q_R$

Answer: $\mathbf{q_A} = w + q_R = 921.487 + 1938.52 =$ **2860.0 kJ/kg**

(e) Thermal efficiency, η_{th}:

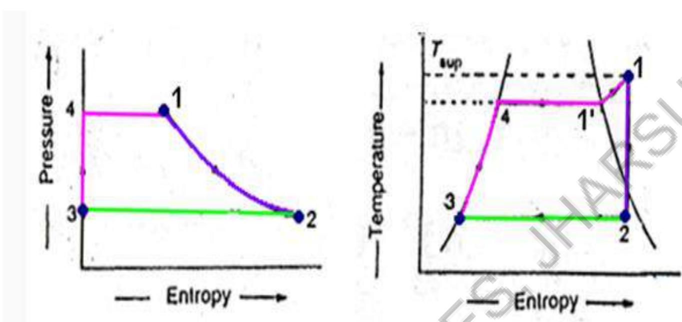
Answer: Thermal efficiency, η_{th} $= \dfrac{\text{Net work done during cycle}}{\text{Heat supplied}} \times 100 = \dfrac{921.487}{2860.0} \times 100$ **= 32.21%**

(f) Theoretical steam consumption:

Answer: Theoretical steam consumption = $\dfrac{3600}{\text{Net work done}} = \dfrac{3600}{921.48}$ = **3.91 kg/kWh**

3: A steam turbine receives superheated steam at a pressure of 17 bar and having a degree of superheat of 110°C. The exhaust pressure is 0.07 bar and the expansion of steam takes place isentropically. Calculate (a) The heat rejected, (b) the heat supplied, (c) net work done, and (d) thermal efficiency. (Neglect pump work)

Solution:



Given: Superheated steam supplied to a turbine at pressure, $p_1 = 17$ bar

Temperature of superheated steam $= t_{s,1} + 110°C$.

Pump work, $w_p = 0$

From Steam table (Dry saturated steam)

At pressure, $p_4 = p_1' = p_1 = 17$ bar $\rightarrow$ $t_{s,1} = 212.4°C$

Therefore, temperature of superheated steam, $t_{sup,1} = 212.4 + 110 = 322.4°C$

From Steam table (superheated steam)

At pressure, $p_1 = 17$ bar and $t_{sup,1} = 322.4°C$ $\rightarrow$ $h_{sup,1} = 3083.4$ kJ/kg, $s_{sup,1} = 6.939$ kJ/kg K

Given: Steam expanded isentropically to pressure, $p_2 = 0.07$ bar.

From Steam table (Dry saturated steam)

At pressure, $p_2 = p_3 = 0.07$ bar $\rightarrow$ $h_{f,3} = 163.4$ kJ/kg, $h_{fg} = 2409.2$ kJ/kg, $s_{f,3} = 0.559$ kJ/kgK, $s_{fg} = 7.718$ kJ/kgK, $v_{f,3} = 0.001$ m^3/kg

(a) Determine heat rejected, q_R

Formula: Heat rejected, $q_R = h_2 - h_{f,3}$

Finding unknown, h_2:

Isentropically expansion, therefore $s_2 = s_{sup,1}$

$= 6.939$

Since for wet steam at point '2', $s_2 = s_{f,3} + x_2\, s_{fg,(p=0.07\ bar)}$

Therefore, $s_{f,3} + x_2\, s_{fg,(p=0.07\ bar)} = 6.939$

$0.559 + x_2(7.718) = 6.939$

$x_2 = 0.827$

Enthalpy for wet steam at point '2', $h_2 = h_{f,3} + x_2 h_{fg,(p=0.07\ bar)}$

$\mathbf{h_2}$ = 163.4 + 0.827 (2409.2) = **2155.8 kJ/kg**

Answer: Heat rejected, $\mathbf{q_R} = h_2 - h_{f,3}$ = 2155.8 - 163.4 = **1992.4 kJ/kg**

(b) Determine heat supplied, q_A

Formula: $q_A = h_{sup,1} - h_{f,3}$

Answer: $\mathbf{q_A} = h_{sup,1} - h_{f,3}$ = 3083.4 – 163.4 = **2920 kJ/kg**

(c) Determine net work done, w :

Formula: Net work done during cycle, w = Heat supplied (q_A) – heat rejected (q_R)

Answer: Net work done during cycle, **w** = (q_A) – (q_R)

= 2920 – 1992.4 = **927.6 kJ/kg**

(d) Thermal efficiency, η_{th}:

Answer: Thermal efficiency, η_{th} $= \frac{\text{Net work done during cycle}}{\text{Heat supplied}} \times 100 = \frac{921.487}{2860.0} \times 100$ **= 31.7%**

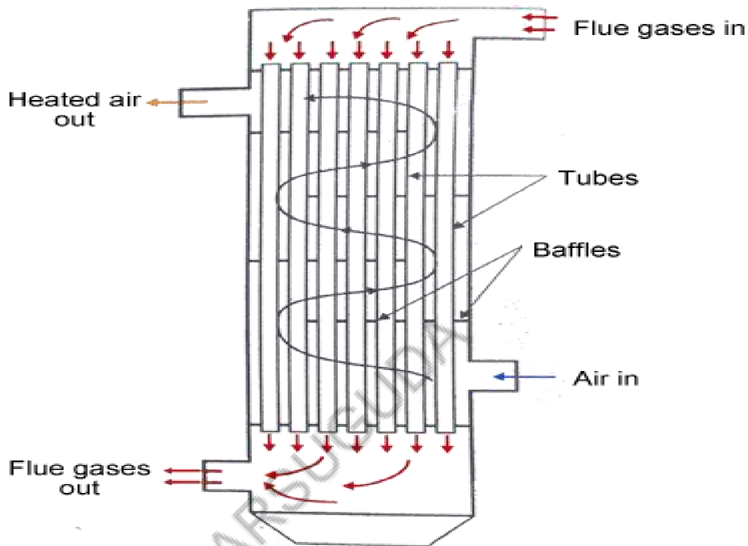
LIST OF THERMAL POWER STATIONS IN INDIA WITH CAPACITY

Name	Location	Capacity
Mundra Thermal Power Station	Gujarat	4,620 MW
Vindhyachal Thermal Power Station	Madhya Pradesh	4,260 MW
Mundra Ultra Mega Power Plant	Gujarat	4,150 MW
KSK Mahanadi Power Project	Chhattisgarh	3,600 MW
Jindal Tamnar Thermal Power Plant	Chhattisgarh	3,400 MW
Tiroda Thermal Power Station	Maharashtra	3,300 MW
Barh Super Thermal Power Station	Bihar	3,300 MW
Talcher Super Thermal Power Station	Odisha	3,000 MW
Sipat Thermal Power Plant	Chhattisgarh	2,980 MW
NTPC Dadri	Uttar Pradesh	2,637 MW
NTPC Ramagundam	Telangana	2,600 MW
Korba Super Thermal Power Plant	Chhattisgarh	2,600 MW
Mejia Thermal Power Station	West Bengal	2,430 MW
Sterlite Jharsuguda Power Station	Odisha	2,400 MW
Kahalgaon Super Thermal Power Station	Bihar	2,340 MW
Chandrapur Super Thermal Power Station	Maharashtra	2,340 MW
Singrauli Super Thermal Power Station	Uttar Pradesh	2,050 MW
Rihand Thermal Power Station	Uttar Pradesh	2,000 MW
Simhadri Super Thermal Power Plant	Andhra Pradesh	2,000 MW
Kudankulam Nuclear Power Plant	Tamil Nadu	2,000 MW
North Chennai Thermal Power Station	Tamil Nadu	1,830 MW
Dr Narla Tata Rao Thermal Power Station	Andhra pradesh	1,760 MW
Kothagudem Thermal Power Station	Telangana	1,720 MW
Anpara Thermal Power Station	Uttar Pradesh	1,630 MW
Trombay Thermal Power Station	Maharashtra	1,580 MW
Suratgarh Super Thermal Power Plant	Rajasthan	1,500 MW
Vallur Thermal Power Project	Tamil Nadu	1,500 MW
Indira Gandhi Super Thermal Power Project	Haryana	1,500 MW

Economizer

Economizer is a heat exchanger device which recover some of the heat from exhaust or flue gas and utilize it for heating feed water. Generally, economizer units are placed between boiler and chimney.
Advantages:
Stress due to uneven expansion is reduced because the temperature range between boiler parts is reduced.
Saving in the Fuel consumption.
Overall efficiency increases.
Evaporative capacity of the boiler is increased.
Protection from chilling of boiler metal.

Air preheater



Air preheater is a device which extract heat from exhaust gas to increase the air temperature before entering the furnace. It accelerates the combustion, enhance the burning of fuel and thus increase thermal efficiency. It is generally placed after the economizer. The degree of preheating depends on the type of fuel and rate at which boiler operates. Another advantage of air preheater is that it Reduce flue gas temperature that allows to simplify the design of ducting for flue gas.

Super heater

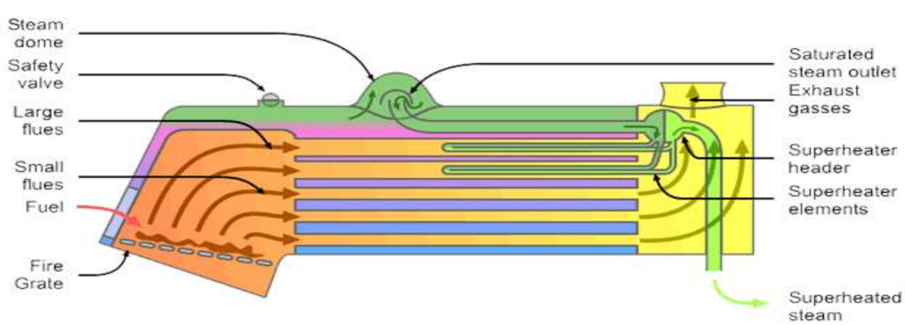


Diagram of a locomotive type fire-tube boiler with superheater.

The steam generated by a boiler is generally wet or at most dry saturated. Super heater is used to increase the temperature of steam above its saturation point, since superheating result in the increase in efficiency and economy of the steam plant.
There are two types of super heater, convective and radiant. Convective type uses heat from flue gases whereas radiant type (placed on combustion chamber) receives heat from burning fuel through the radiant process.

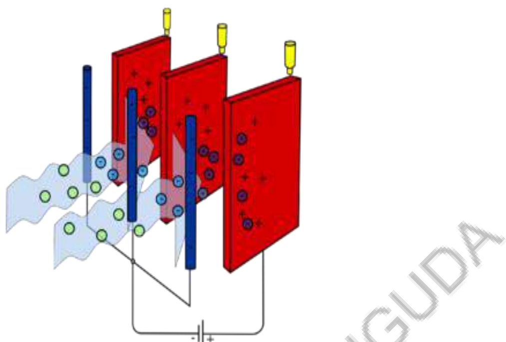
Advantages:
Steam consumption is reduced.

Protection from erosion of turbine.
Losses due to condensation of steam in the cylinders and pipes are reduced.
Plant efficiency increases.

Electrostatic precipitator:

Electrostatic precipitator is a type of filter (dry scrubber) that uses static electricity to remove soot and ash from exhaust fumes before they exit the smokestacks. This one common air pollution control device.

The operation of electrostatic precipitators is fairly simple. The dirty flue gas escaping through the smokestack is passed through two electrodes. The shape these electrodes take depends on the type of electrostatic precipitator used, but they can be metal wires, bars, or plates inside a pipe or the smokestack itself. One of the electrodes is charged with a high negative voltage, and this plate causes particulates inside the smoke to obtain a negative charge as they pass by this electrode. Further along the pipe, the second electrode carries a similarly high positive voltage. Based solely on the fact that opposite charges attract, the negatively charged soot particles are pulled towards the positive electrode and stick to it. Occasionally these plates must be cleaned to remove the accumulated soot and dispose of it into a hopper. The soot and ash collected from coal burning power plants in this manner is referred to as fly ash.



A model of an electrostatic precipitator using metal wires as the negative electrodes and large plates as the positive electrodes.

Though most electrostatic precipitators work in a similar way, there are many variations and different types that work better for different sized particles, different smoke compositions, and different amounts of pollution. The need for a variety of designs comes partly from the fact that coal burned around the world varies in its chemical composition drastically. Other power plants may look to remove certain pollutants - such as sulfur dioxide - or look to minimize the amount of ash produced. Additionally, some low-sulfur coals that are burned have a higher electrical resistivity, which makes it more difficult to remove the ash produced by this coal using electrostatic precipitators.

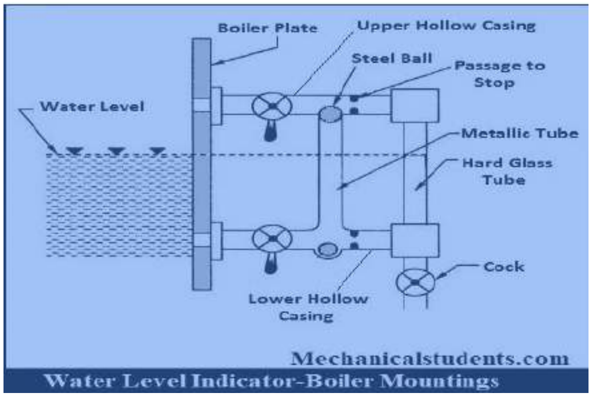
Boiler Mountings:

The Boiler Mountings are as follows:

- **Water Level Indicator**
- **Blow off cock**
- **Feed check valve**
- **Safety Valves**
- **Pressure Gauge**
- **Fusible Plug**

The detailed explanation of Boiler Mountings are shown below.

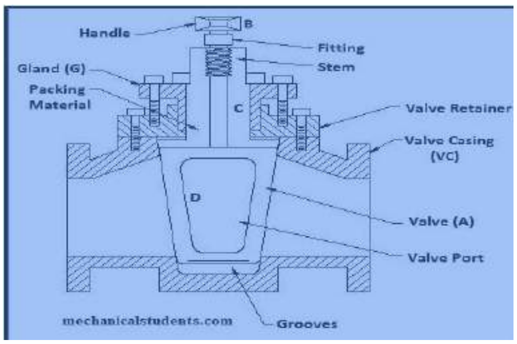
1.Water Level Indicator:



Water Level Indicator-Boiler Mountings

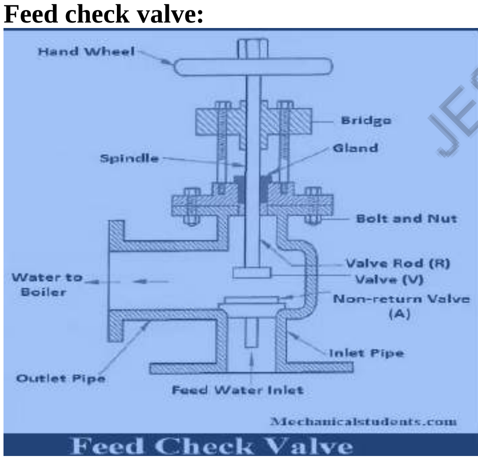
It is fitted on the boiler so that we can come to know, how much water level was present in the bolier such that suitable steam can be generated from it.

Blow off cock:



The function of Blow off cock is to empty the boiler by removing water, mud and sediments which are collected at the bottom of the boiler shell.

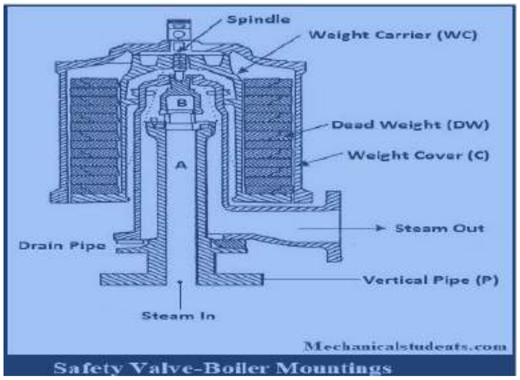
Feed check valve:



Feed Check Valve

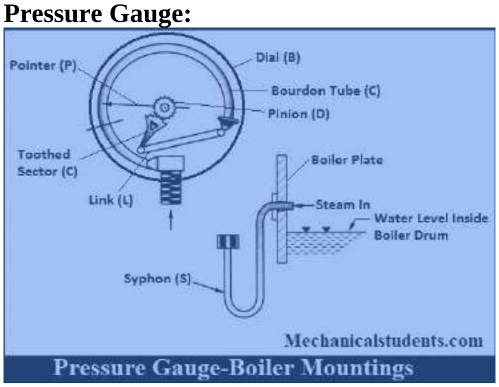
The main function of Feed Check Valve is to regulate the supply of water which is pumped into the boiler by employing feed pump.

Safety Valves:



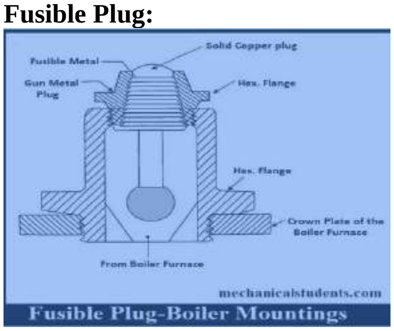
They are generally used to avoid the exposion takes place inside the boiler shell due to the excess pressure. When the pressure crosses the critical pressure, then the safety valve opens which allows excess steam to escape into the atmosphere untill the pressure inside the shell reaches normal pressure.

Pressure Gauge:



The Pressure gauge used in the boiler is especially of Bourdan type which is used to measure the pressure inside the boiler shell.

Fusible Plug:

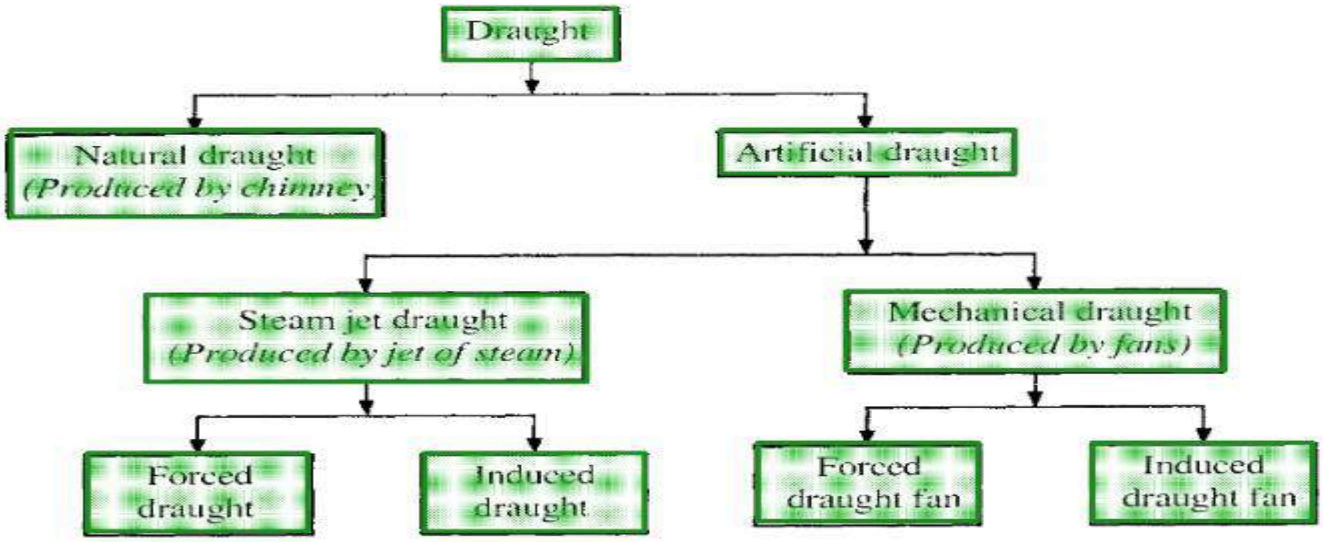


The fusible plug is placed at the top of the firebox whose duty is to avoid the explosion taking place due to the overheating of furnace when the water level in the boiler falls to an unsafe limit and it extinguish fire in the furnace.

It is fitted on the boiler so that we can come to know, how much water level was present in the bolier such that suitable steam can be generated from it.

<u>DRAUGHT</u>

To move the air through the fuel bed and to produce a flow of hot gases through the boiler, economizer, preheater and chimney require a difference of pressure require a difference of pressure. This difference of pressure for to maintaining the constant flow of air and discharging the gases through the chimney to atmosphere is known as draught.



ADVANTAGES OF NATURAL DRAUGHT/ CHIMNEY:

ADVANTAGES :

(1) It does not require any external power for producing the draught.
(2) The capital investment is less. The maintenance cost is nil as there is no mechanical part.
(3) Chimney keeps the flue gases at a high place in the atmosphere which prevents the contamination of atmosphere.
(4) It has long life.

LIMITATIONS :

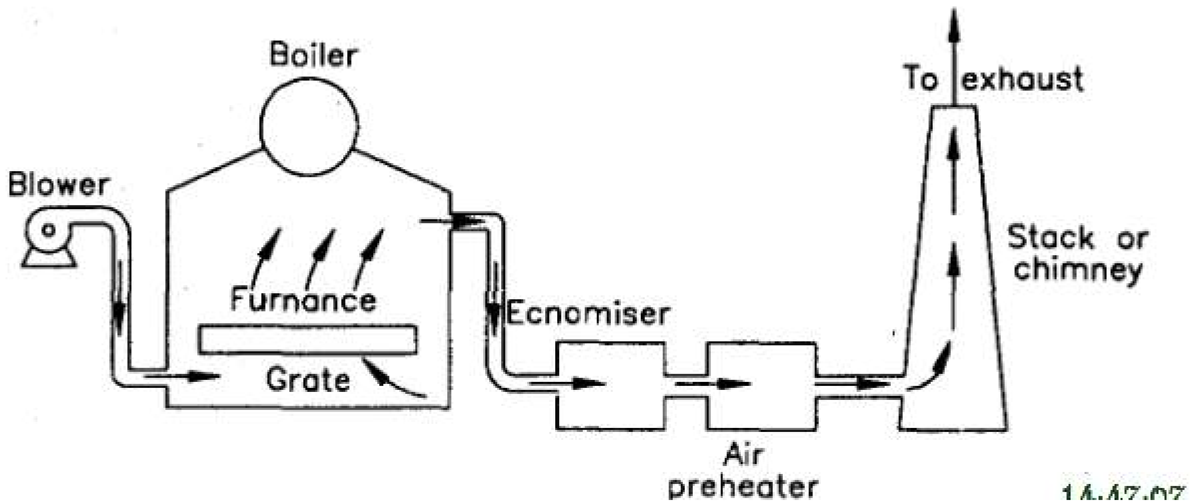
(1) The maximum pressure available for producing natural draught by chimney is hardly 10 to 20 mm of water under the normal atmosphericand flue gas temperatures.
(2) The available draught decreases with increase in outside air temperature and for producing sufficient draught, the flue gases haveto be discharged at comparatively high temperatures resulting in the loss of overall plant efficiency. And thus maximum utilization of heat is not possible.
(3) As there is no through mixing of air and fuel in the combustion chamber due to low velocity of air therefore combustion is very poor. This increases the specific fuel consumption.
(4) The chimney has no flexibility to create more draught under peak load conditions because the draught available is constant for a particular height of chimney and the draught can be increased by allowing the flue gases to leave the combustion chamber at higher temperatures. This reduces the overall efficiency of the plant.
Nearly 20% heat released by the fuel is lost to the flue gases. The chimney draught is only used for very small boilers. Nowadays the chimney is never used for creating draught in thermal power plants as it has no flexibility, the total draught produced is insufficient for high generating capacity.
The chimney is used in all power plants only to discharge the flue gases high in the atmosphere to maintain the cleanliness of the surrounding atmospheric air.

Why artificial draught ? ? ?

Because of insufficient head and lack of flexibility.The use of natural draught is limited to small capacity boilers only. The draught required in actual power plant is sufficiently high (300 mm of water) and to meet high draught requirements,some other system must be used[known as artificial draught].The artificial draught is more economical when the required draught is above 40 mm of water.

FORCED DRAUGHT

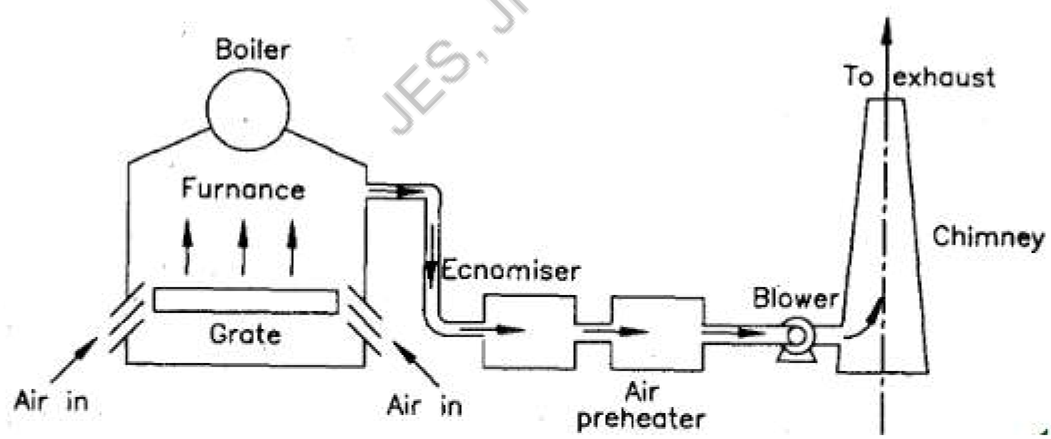
In a forced draught system, a blower is installed near the base of the boiler. This draught system is known as positive draught system or forced draught system because the pressure of air throughout the system is above atmospheric pressure and air is forced to flow through the system. The arrangement of the system is shown in figure.



INDUCED DRAUGHT

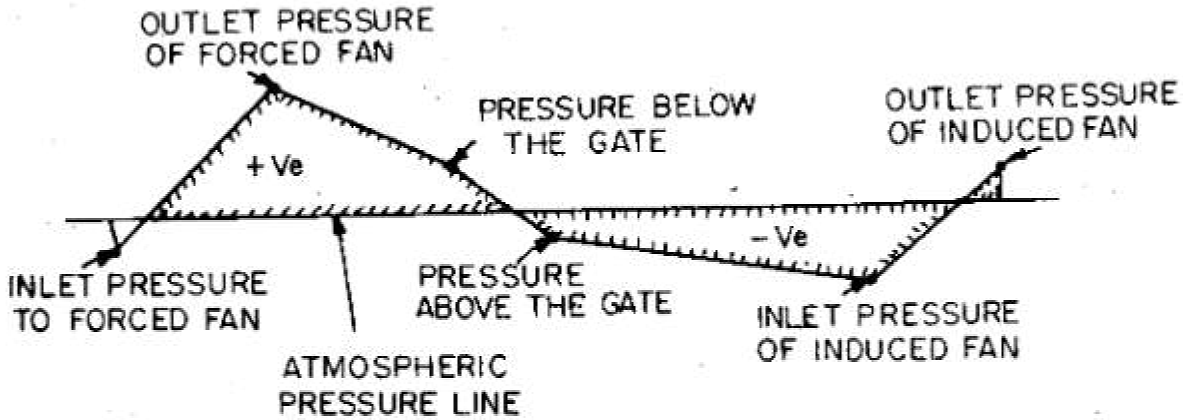
In this system, the blower is located near the base of the chimney instead of near the grate. The air is sucked in the system by reducing the pressure through the system below atmosphere. The action of the induced draught is similar to the action of the chimney. The draught produced is independent of the temperature of the hot gases therefore the gases may be discharged as cold as possible after recovering as much heat as possible in air-preheater and economiser.

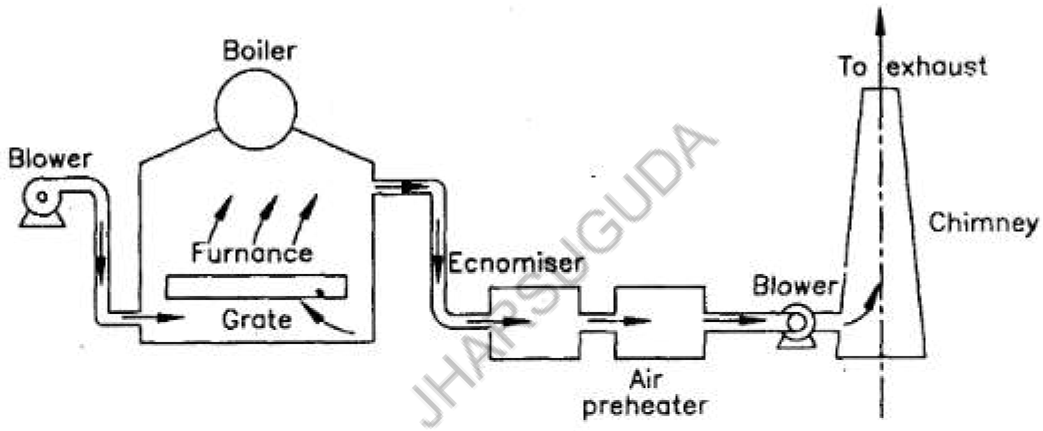
This draught is used generally when economiser and air-preheater are incorporated in the system. The fan should be located at such a place that the temperature of the gas handled by the fan is lowest. The chimney is also used in this system and its function is similar as mentioned in forced draught but total draught produced in induced draught system is the sum of the draughts produced by the fan and chimney.



BALANCED DRAUGHT:

The balanced draught is a combination of forced and induced draught. If the forced draught is used alone, then the furnace cannot be opened either for firing or inspection because the high pressure air inside the furnace will try to blow out suddenly and there is every chance of blowing out the fire completely and furnace stops. If the induced draught is used alone, then also furnace cannot be opened either for firing or inspection because the cold air will try to rush into the furnace as the pressure inside the furnace is below atmospheric pressure. This reduces the effective draught and dilutes the combustion. To overcome both the difficulties mentioned above either using forced draught or induced draught alone, a balanced draught is always preferred





Advantages of mechanical draught over natural draught.

1. The artificial mechanical draught is better in control and more economical than natural draught.
2. The rate of combustion is high as the available draught is more.The better distribution and mixing of air with fuel is possible therefore the quantity of air required per kg of fuel is less.
3. The air flow can be regulated according to the requirement by changing the draught pressure.
4. The chimney draught is produced at the cost of thermal efficiency of the plant because it is necessary to exhaust the gases at high temperature to produce the draught. In mechanical draught, the exhaust gases can be cooled to lowest possible temperature before exhaust and improves the overall thermal efficiency of the plant.
5. The height of the chimney used in mechanical draught can be reduced sufficiently as the function of the chimney is only to exhaust the gases high in the atmosphere to prevent the contamination.
6. The efficiency of the artificial draught is nearly 7% whereas the efficiency of the chimney draught is hardly 1%.
7. The fuel consumption per kW due to artificial draught is 15% less than the natural draught.
8.The fuel burning capacity of the grate is 200 to 300 kg/m^2 in area of the grate per hour with mechanical draught whereas it is hardly 50kg/m2-hr with natural draught.
9. It prevents the formation of smoke as complete combustion is possible even with less excess air.

The major disadvantage of the artificial draught is the high capital cost required and high running and maintenance costs of the fans used.

STEAM TURBINE:

The steam turbine is a prime-mover in which the potential energy of the steam is transformed into kinetic energy, and latter in its turn is transformed into the mechanical energyof rotation of the turbine shaft. The turbine shaft, directly or with the help of a reduction gearing, is connected with the driven mechanism. Depending on the type of the driven mechanism a steam turbine may be utilised in most diverse fields of industry, for power generation and for transpost. Transformation of the potential energy of the steam into the mechanical energy of rotation of the shaft is brought about by different means.

Advantages of steam turbines:

- Since the steam turbine is a rotary heat engine, it is particularly suited to be used to drive an electrical generator.
- Thermal efficiency of a steam turbine is usually higher than that of a reciprocating engine.
- Very high power-to-weight ratio, compared to reciprocating engines.
- Fewer moving parts than reciprocating engines.
- Steam turbines are suitable for large thermal power plants. They are made in a variety of sizes up to 1.5 GW (2,000,000 hp) turbines used to generate electricity.
- In general, steam contains high amount of enthalpy (espacially in the form of heat of vaporization). This implies lower mass flow rates compared to gas turbines.
- In general, turbine moves in one direction only, with far less vibration than a reciprocating engine.
- Steam turbines have greater reliability, particularly in applications where sustained high power output is required.

Disadvantages

Although approximately 90% of all electricity generation in the world is by use of steam turbines, they have also some disadvantages.

- Relatively high overnight cost.
- Steam turbines are less efficient than reciprocating engines at part load operation.
- They have longer startup than gas turbines and surely than reciprocating engines.
- Less responsive to changes in power demand compared with gas turbines and with reciprocating engines.

Principal components

The main parts of a steam turbine are
(1) the rotor that carries the blading to convert the thermal energy of the steam into the rotary motion of the shaft,
(2) the casing, inside of which the rotor turns, that serves as a pressure vessel for containing the steam (it also accommodates fixed nozzle passages or stator vanes through which the steam is accelerated before being directed against and through the rotor blading),
(3) the speed-regulating mechanism, and
(4) the support system, which includes the lubrication system for the bearings that support the rotor and also absorb any end thrust developed.

Classification of steam

Turbine Classification of steam turbines may be done as following:
1. According to action of steam

(a) Impulse turbine
(b) Reaction turbine
(c) Combination of both

2. According to direction of flow:

(a) Axial flow turbine
(b) Radial flow turbine

3. According to number of stages

(a) Single stage turbine
(b) Multi stage turbine

4 .According to steam pressure at inlet of Turbine:

(a) Low pressure turbine
(b) Medium pressure turbine.

(c) High pressure turbine
(d) Super critical pressure turbine.

5.According to method of governing:

(a) Throttle governing turbine.

(b) Nozzle governing turbine.

(c) By pass governing turbine.

6. According to usage in industry:

(a) Stationary turbine with constant speed.

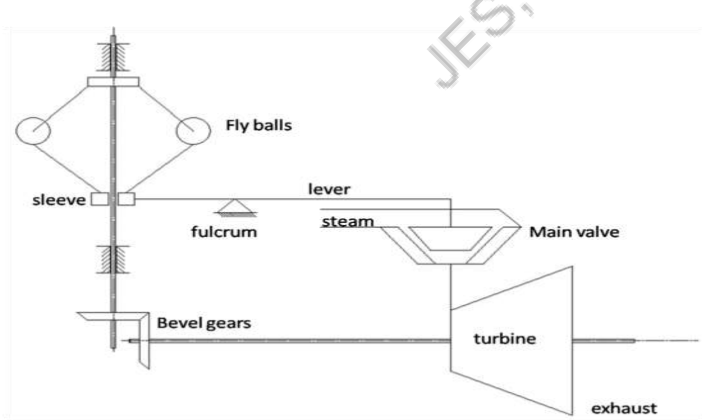
(b) Stationary turbine with variable speed.

(c) Non stationary turbines

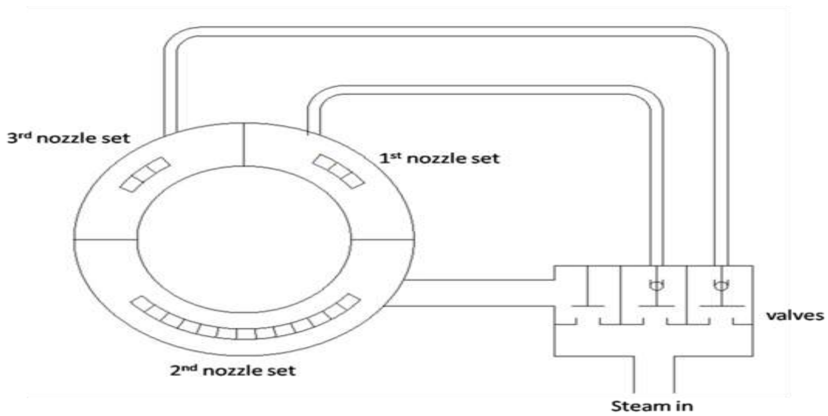
GOVERNING OF STEAM TURBINE

Steam turbine governing is the procedure of controlling the flow rate of steam to a steam turbine so as to maintain its speed of rotation as constant. The variation in load during the operation of a steam turbine can have a significant impact on its performance. In a practical situation the load frequently varies from the designed or economic load and thus there always exists a considerable deviation from the desired performance of the turbine.[1] The primary objective in the steam turbine operation is to maintain a constant speed of rotation irrespective of the varying load. This can be achieved by means of governing in a steam turbine. There are many types of governors.

Throttle governing
In throttle governing the pressure of steam is reduced at the turbine entry thereby decreasing the availability of energy. In this method steam is passed through a restricted passage thereby reducing its pressure across the governing valve. The flow rate is controlled using a partially opened steam control valve. The reduction in pressure leads to a throttling process in which the enthalpy of steam remains constant.

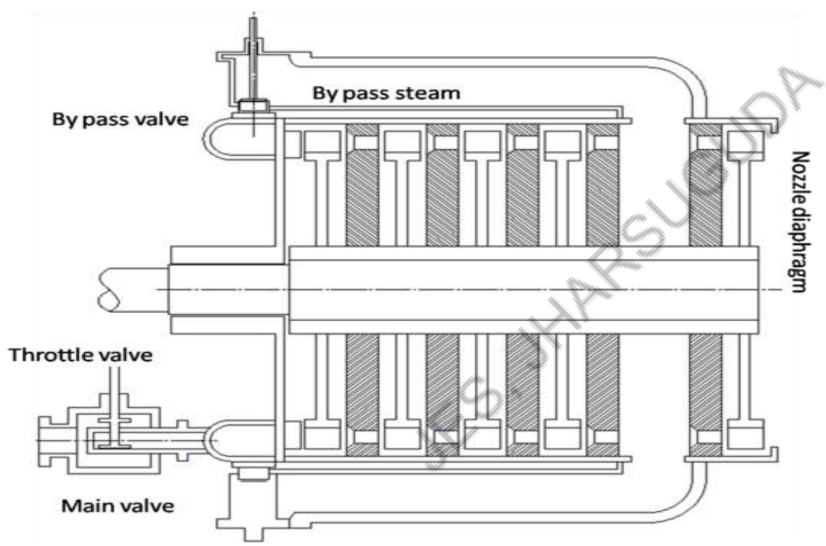


Nozzle governing
In nozzle governing the flow rate of steam is regulated by opening and shutting of sets of nozzles rather than regulating its pressure .In this method groups of two, three or more nozzles form a set and each set is controlled by a separate valve. The actuation of individual valve closes the corresponding set of nozzle thereby controlling the flow rate. In actual turbine, nozzle governing is applied only to the first stage whereas the subsequent stages remain unaffected. Since no regulation to the pressure is applied, the advantage of this method lies in the exploitation of full boiler pressure and temperature. Figure 2 shows the mechanism of nozzle governing applied to steam turbines. As shown in the figure the three sets of nozzles are controlled by means of three separate valves.



By pass governing

Occasionally the turbine is overloaded for short durations. During such operation, bypass valves are opened and fresh steam is introduced into the later stages of the turbine. This generates more energy to satisfy the increased load. The schematic of bypass governing is as shown in figure3.



Combination governing

Combination governing employs usage of any two of the above mentioned methods of governing. Generally bypass and nozzle governing are used simultaneously to match the load on turbine as shown in figure 3.

Emergency governing

Every steam turbine is also provided with emergency governors which come into action under the following condition.

- When the mechanical speed of shaft increases beyond 110%.
- Balancing of the turbine is disturbed.
- Failure of the lubrication system.
- Vacuum in the condenser is quite less or supply of coolant to the condenser is inadequate.

STEAM CONDENSOR

A steam condenser is a closed vessel heat exchanger that is used to convert low-pressure steam to water. The pressure inside a steam condenser is kept below the atmospheric pressure to increase efficiency. It is generally used for lowering the backpressure of the exhaust of the turbine end.

It works to achieve two main objectives

- 1. To maintain low pressure (below atmospheric pressure) at the outlet of the steam turbine so as to obtain the maximum possible energy.
- 2. To supply pure feed water to the hot well and from hot well the water is again pumped to the boiler with the help of boiler feed pump

Condensor auxillaries

The principle requirements of steam condensing plant are:

1. Condenser: It is a closed vessel used to condense the steam. The low pressure steam gives off heat to its coolant here (water from cooling tower) and gets converted into water during the process of condensation.

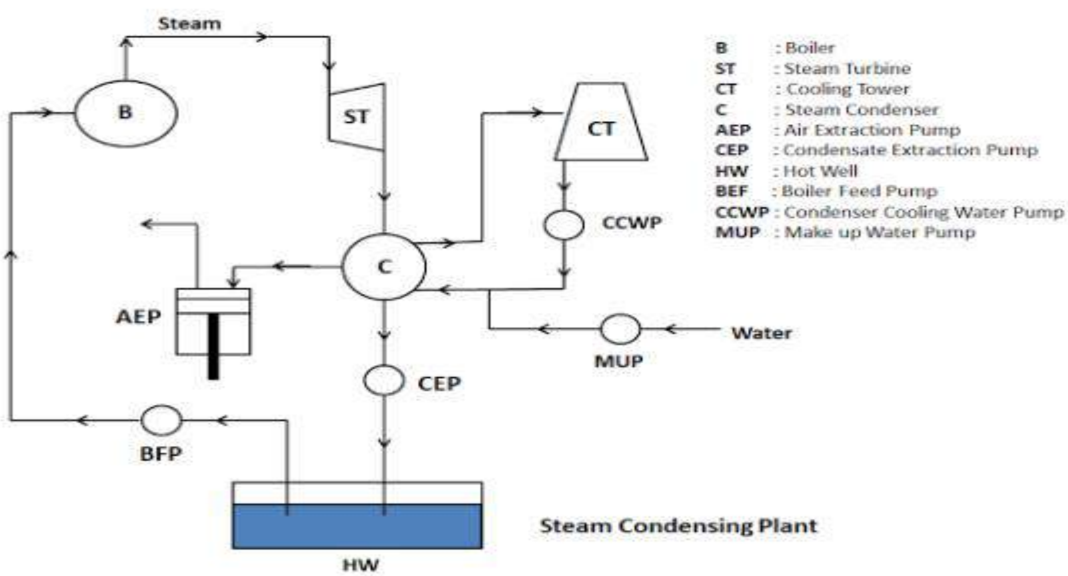
2. Condensate Extraction Pump: It is a pump which is installed in between the condenser and hot well. It transfers the condensate from the condenser to the hot well.

3. Hot Well: It is a sump that lies in between the condenser and boiler. It receives the condensate from the condenser by condensate pump. The feed water is transferred from the hot well to the boiler.

4. Boiler Feed Pump: It is a pump installed in between the hot well and boiler. It pumps the feed water from the hot well to the boiler. And this is done by increasing the pressure of condensate above boiler pressure

5. Cooling Tower: It is a tower which contains the cold water and this water ismade to circulate within the condenser for cooling of steam.

6. Cooling Water Pump: It is a pump lies in between the cooling tower and condenser. It circulates the cooling water through the condense.



Classifications of Steam Condenser:

The condenser can be broadly classified into two types:

1. **Direct Contact type Condenser**
2. **Surface Condenser**

Direct Contact type Condenser:

In direct contact type condenser the steam (Condensate) and the cooling water mixes and come together as a single stream. It's generally available in the market as a low cost, and the design of this type of condenser is pretty much simple. However, where the mixture of cooling water and condensate is not permissible we can't use this type of condenser. Direct contact type condenser is three types:

1. Jet Condenser
2. Barometric Condenser
3. Spray Condenser

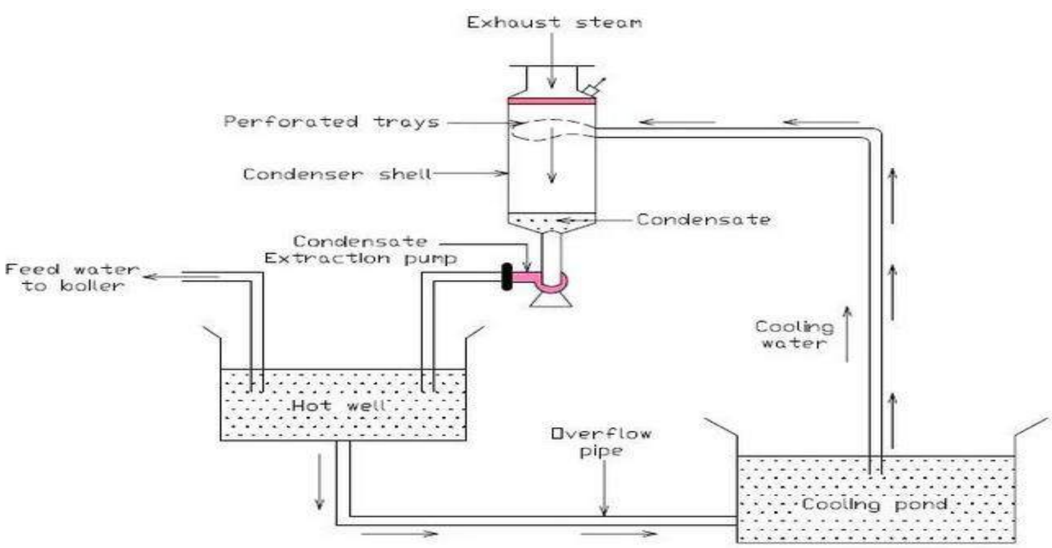
Jet Condenser:

As it is one type of direct contact type condenser that's why here condensate and the cooling water is mix together and comes out. Here as the steam comes with the cooling water that's why recirculating of the cooling water to the boiler is not possible until it passes through a water treatment plant.
However, the condensing capability of the jet condenser is very much higher than the other.
The jet condenser can be categorized into 4 more types:

- Parallel flow jet condenser
- Counterflow or Low-level jet condenser
- Barometric or High-level jet condenser
- Ejector Condenser

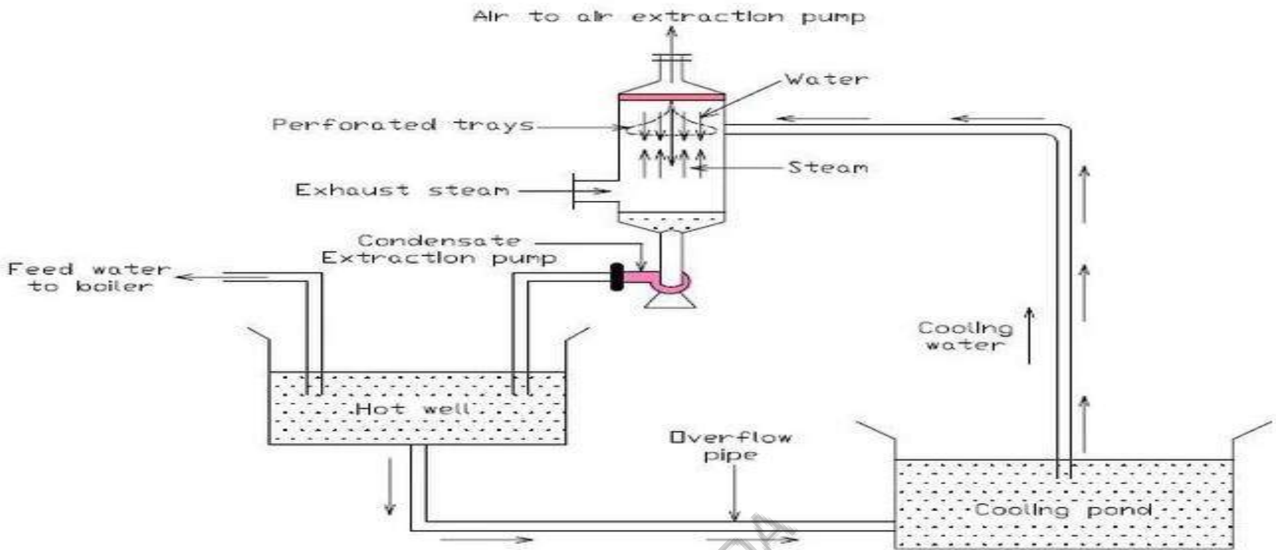
Parallel Flow Jet Condenser:

In a parallel flow jet condenser, the direction of flow of the steam and the direction of flow of the cooling water is same, both of this comes from the top of the condenser and comes out after mixing from the bottom of the condenser.



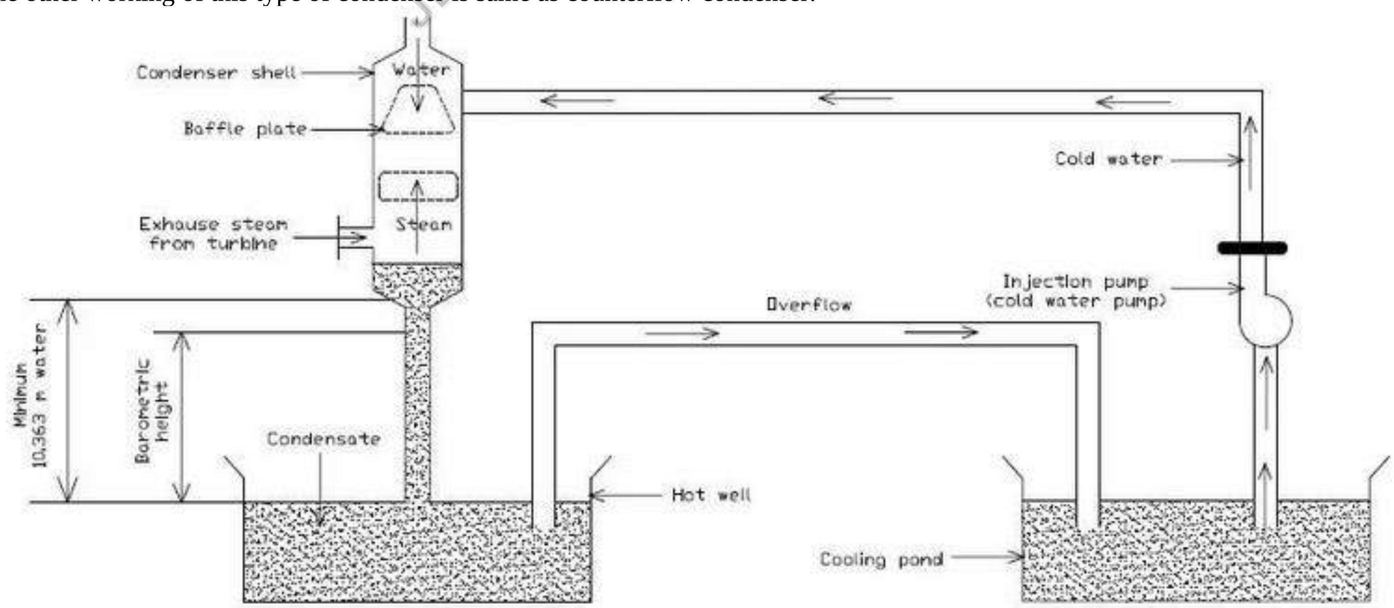
Counter flow or Low-level Jet Condenser:

It is just the opposite of parallel flow jet condenser, here cooling water comes from the top of the condenser, and exhaust steam enters to the condenser from the bottom side section of the condenser. So the direction of the cooling water is downwards, and the direction of exhaust steam is upward. That's why this type of condenser is called counterflow condenser.



Barometric or High-level Jet Condenser:

In the barometric condenser, the condenser shell is fitted above the hot well at a height of 10.36 m. To achieve this the discharge section of this type of condenser is fitted with a long vertical pipe, or it is also called tailpipe.
In this type of condenser, there is no condensate extraction pump is there, the flow is completely done by the help of gravitational force.
However, a cooling water injection pump is there to deliver the cooling water from the top of the condenser.
The other working of this type of condenser is same as counterflow condenser.

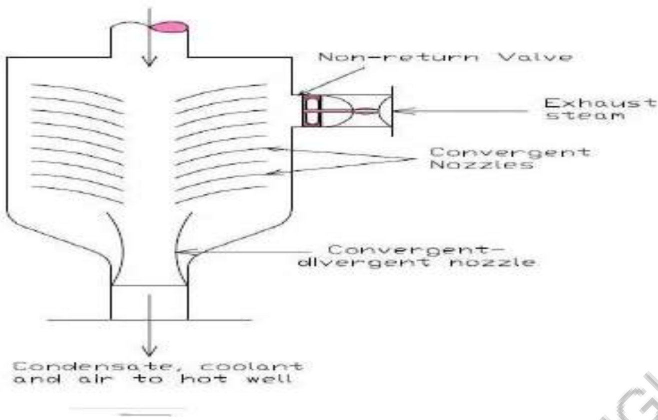


Ejector Condenser:

An ejector condenser has a no-return valve through which exhaust steam enters to the condenser.

It also has several convergent nozzles which help to decrease the pressure of the inner section of the condenser, hence due to low pressure, the exhaust steam draws into the condenser through the no-return valve, and mixes with the cooling water and condensate.

In the end, there is again a divergent nozzle where the kinetic energy is again converted to the pressure energy, and increase the pressure at the exhaust of the condenser which helps to extract the condensate out of the condenser.



Surface Condenser:

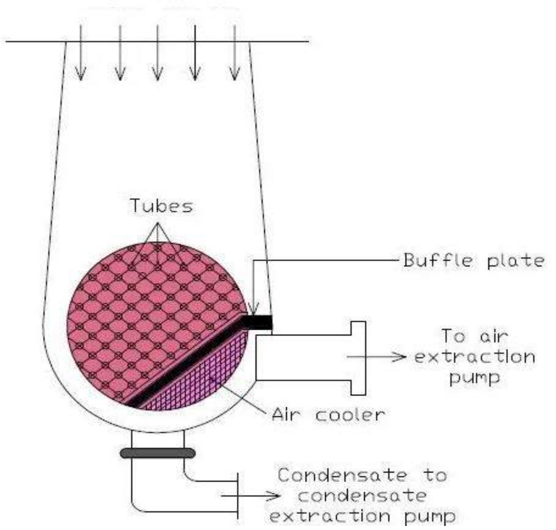
Surface condensers are generally used in the power plant. This type of condenser is also called shell and tube type condenser.
Here there is no contact between exhaust steam and cooling water. So the extracted condensate can be reused in the boiler without any water treatment.
Within the condenser space, there are several horizontal tubes, inside which cooling water is flowing. At the above portion of the condenser, the exhaust steam enters and flowing downwards, when the steam in contact with the tubes inside which cooling water is flowing, the steam gets condensed, here the heat transfer is done by conduction and/or convection. A condensate extraction pump is fitted at the bottom which helps to extract the condense water from the condenser.
Also in this type of condenser, there is a tube sheet is fitted at each end of the condenser where the water tubes are rolled to avoid leakage.
Surface Condenser is categorized into four types:

- Downflow surface condenser
- Central flow condenser
- Regenerative condenser
- Evaporative condenser

Down flow Surface Condenser:

In downflow surface condenser exhaust steam from the prime over enters from the top of the condenser and flows downwards due to the gravitational force and the effect of air-extraction pump.
When the steam flows downwards it's in touch with several cooling tubes and lose the heat and get condensed. Later on the condense water extract from the bottom surface of the condenser by the help of Condensate Extraction Pump.

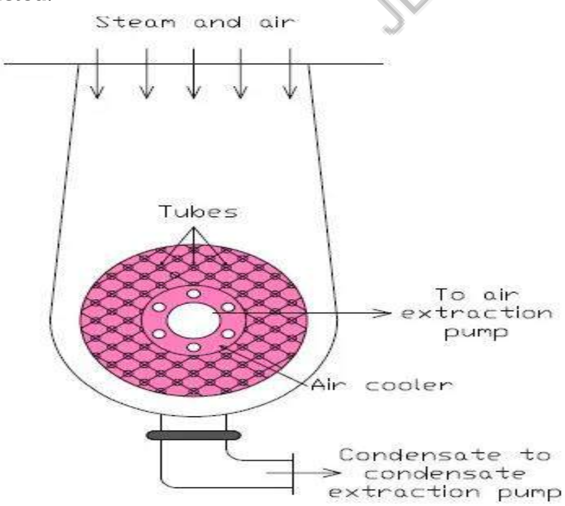
Steam and air in



Central Flow Condenser:

In this type of condenser, steam enters from the top of the condenser. The suction end of the air extraction pump is fitted at the centre of the condenser or tube.

Due to this design, steam is forcefully passed radially which ensure better heat transfer as the contact area of tubes and steam is now more. After heat exchange, the condensate stored at the bottom of the condenser and by the help of condenser removal pump it is extracted.



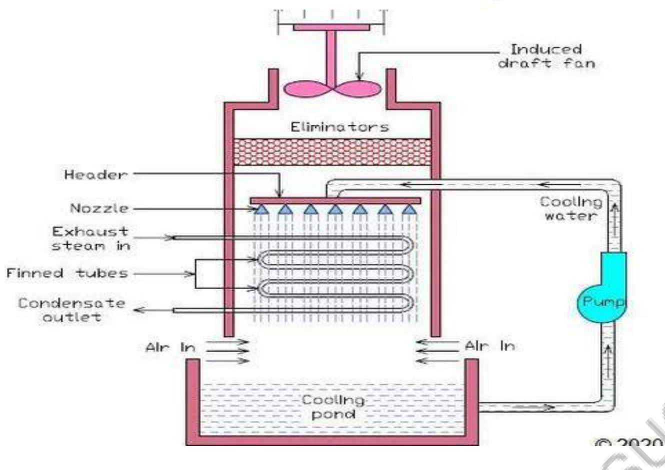
Central Flow Condenser Diagram

Regenerative Condenser:

In this type of condenser, the condensate is also heated by the help of exhaust steam which comes into the condenser, and then the condensate is feed to the steam generator. It dramatically improves the efficiency of the steam generation plant.

Evaporative Condenser:

Here the exhaust steam comes from the turbine enters into the condenser within a tube. At the above section of the condenser, there are a couple of nozzles fitted from which cooling water is sprayed.
When the cooling water is coming into the contact with the tube inside which steam is following then some portion of the cooling water is absorbed heat and vapourised. As the heat is now taken from the steam so it is now converted into water and collected outside of the condenser



Applications of Steam Condenser:

The applications of Steam Condenser are listed below:

- Condenser like surface condenser is used in the thermal power plant to condensate the exhaust steam from the turbine.
- Steam condensers are used in many food processing industries as well.

Advantages of Steam Condenser:

As there are two types of condenser available one is direct contact condenser, and the other one is the surface condenser, so it obvious that their advantages will be different as well.

Advantages of Direct Contact Condenser:

- The jet condenser is simple in design.
- Built-in cost is very much less.

Advantages of Surface Condenser:

- In the case of surface condenser, it dramatically improves the vacuum efficiency.
- As in surface condenser, there is no mixing occurs, so we can get the pure condensate which can be reused in the boiler.
- Quantity of the cooling water needed for heat exchange purpose is relatively low.

Disadvantages of Steam Condenser:

Steam Condenser also have some disadvantages, they are listed below according to the types:

Disadvantages of Direct Contact Condenser:

- As cooling water and condensate come out in one stream, so here it is not possible to reuse the condensate without water treatment.
- Vacuum efficiency is low in direct contact condenser like the jet condenser.

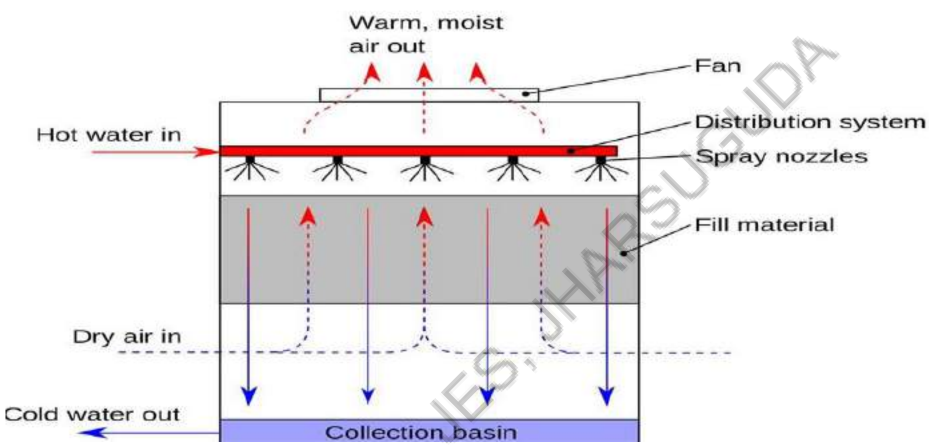
Disadvantages of Surface Condenser:

- Design is complicated so the initial cost is more.
- The maintenance cost of this type of condenser is relatively higher.
- The size of this type of condenser s large so needs more floor space.

COOLING TOWER

Cooling towers are primarily used for heating, ventilation, and air conditioning (HVAC) and industrial purposes. Cooling towers provide a cost-effective and energy efficient operation of systems in need of cooling. More than 1,500 industrial facilities use large quantities of water to cool their plants . HVAC systems are used typically in large office buildings, schools, and hospitals. Industrial cooling towers are larger than HVAC systems and are used to remove heat absorbed in the circulating cooling water systems used in power plants, petroleum refineries, petrochemical plants, natural gas processing plants, food processing plants, and other industrial facilities.

Working:Air conditioning equipment and industrial processes can generate heat in the form of tons of hot water that needs to be cooled down. That's where cooling towers come in. Overheated water flows through the cooling tower where it's recirculated and exposed to cool, dry air. Heat leaves the recirculating cooling tower water through evaporation. The colder water then reenters the air conditioning equipment or process to cool that equipment down, and the cooling cycle repeats over and over again. When the warm condenser goes into the cooling tower, the water is passed through some nozzles which is sprayed into small droplets across the fill, which increases the surface area of water and allows for better heat loss thru greater evaporation. The purpose of the fan on top of the cooling tower is to bring in air from the bottom of the tower and move it up and out in the opposite direction of the warm condenser water of the top of the unit. The air will carry the heat through evaporating water of the cooling tower into the atmosphere.



Types of Cooling Tower

There are two main categories of cooling towers.

1. Natural draft cooling tower
2. Mechanical draft cooling tower

1 Natural draft cooling tower

The natural draft atmospheric cooling tower consists of a sump and arrangement for the spray of water from the height of about 5 m to 8 m . It is necessary to provide side louvers to minimize carry over water loss. The warm water from the condenser is nuzzled and the cooled water is collected in the sump constructed at the bottom. The performance of this cooling tower varies due to variation of air velocity and it requires more space for the installation of the cooling tower.

2 Mechanical draft cooling tower

In case of mechanical draft, fan or blower is used to supply the air through the cooling tower. In recent design of the cooling tower, warm water is passed over the supporting medium in form of thin sheet and air is blown through the cooling tower. Induced draft cooling is preferred over the forced draft cooling tower as air distribution is more uniform in induced draft cooling tower.

Spray ponds:

A **spray pond** is a reservoir in which warmed water (e.g. from a power plant) is cooled before reuse by spraying the warm water with nozzles into the cooler air.
The added features of the spray ponds are the sprays themselves. Because the sprays increase the water surface area in contact. With the air and increase the relative velocity between the air and the water, spray ponds can produce as much as a 20-fold decrease in pond size over that of a straight cooling pond with the same heat load.
However, the optimistic claims made for the spray ponds should be tempered by the following adverse conditions:
(a) the increase in the local wet bulb temperature in a field of sprays,
(b) the short period of contact time between air and water during an efficient mode of heat transfer (that is, the. time period before a large increase in local wet bulb temperature occurs), and
(c) water losses due to drift and evaporation.

Efficiencies of Turbines

The efficiency of the turbine is lower than the ideal efficiency determined from the velocity diagram due to several energy losses in *the system, as discussed above.*
Thermal efficiency of steam turbine depends on the following factors:

- Steam pressure and temperature at throttle valve of the turbine
- Exhaust steam pressure and temperature.
- Number of bleedings.

The efficiency of steam turbines can be increased by adopting following measures:
a)by using superheated steam
b)by using bled steam, as it reduces the heat rejected to the condenser.

i)Blade or velocity diagram efficiency:

$$\eta_b = \frac{2u(V_{wi}+V_{w0})}{V_i^2}$$

where η_b = blade efficiency
V_{wi} = velocity of whirl at inlet
$V_{w0} = velocity\ of\ whirl\ at\ outlet$
V_i = absolute velocity at the inlet of the blade
u =velocity of flow at inlet

ii)Stage efficiency: This covers all the losses on the nozzles, blades, diaphragms and disc that are associated with that stage.

$$\text{Stage } \eta = \frac{Net\ work\ done\ on\ the\ blades - Disc\ friction\ and\ windage}{Adiabatic\ heat\ drop\ per\ stage}$$

iii)Internal efficiency: This is equivalent to the stage efficiency when applied to the whole turbine, and is defined as

$$\eta_i = \frac{Heat\ converted\ into\ useful\ work}{Total\ adiabatic\ heat\ drop}$$

Assuming stage η constant, for all stages, then,
η_i= stage η × reheat factor

iv)Overall or turbine efficiency(η_o): This efficiency covers internal and external losses, for example, bearing and steam friction, leakage, radiation,etc.,

v)The net efficiency or the efficiency ratio: It is the ratio of= $\frac{Brake\ thermal\ efficiency}{Thermal\ efficiency\ on\ the\ rankine\ cycle}$

It is the overall or net efficiency that is meant when the efficiency of the turbine is spoken without its qualifications.

<u>TURBINE STEAM RATE:</u>

Turbine steam rate is defined as the weight of steam required in kg/hr to develop unit power.
Theoretically, steam rate can be calculated as = $\frac{860}{total\ adiabatic\ heat\ drop}$ (in MKS)
= $\frac{3600}{total\ adiabatic\ heat\ drop}$ (in SI)
Actual steam rate is greater than theoretical steam rate and can be found out by dividing the latter by the overall efficiency,i.e,

Actual steam rate = $\frac{Theoretical\ steam\ rate}{\eta_0}$

STEAM TURBINE PERFORMANCE

Turbine performance can be expressed by the following factors:

1. Losses
2. Thermal efficiency
3. Steam flow rate through the unit
4. The steam flow process through the unit-expansion line or condition curve.

For successful operation of a steam turbine it is desirable to supply steam at a constant pressure and temperature. Steam pressure can easily be regulated by means of a safety valve fitted on boiler. The steam temperature may fluctuate because of the following reasons:

(i)variation in heat production due to varying amounts of fuel burnt according to changing loads.
(ii)fluctuation in quantity of excess air.
(iii)variation in moisture content and temperature of air entering the furnace.
(iv) variation in temperature of feed water
(v)the varying condition of cleanliness of heat absorbing surface.

1.Losses in steam turbine are:

1.losses in regulating valve, moving blade,nozzles,thermal loss
2, winding losses,leakage loss etc.
3.losses in moving blades.

Site selection for a steam power station:

The following points should be considered while site selection of steam power station :

(i) Supply of fuel: The steam power plant should be located near the coal mines so that transportation cost of fuel is minimum.However, if such a plant is to be installed at a place where coal is not available, then care should be taken that adequate facilities exist for the transportation of coal.

(ii) Availability of water: As huge amount of water is required for the condenser, therefore, such a plant should be located on the bank of a river or near a canal to ensure the continuous supply of water.

(iii) Transportation facilities: A modern steam power plant often requires the transportation of material and machinery.Therefore, adequate transportation facilities must exist i.e., the plant should be well connected to other parts of the country by rail, road. etc.

(iv) Cost and type of land: The steam power station should be located at a place where land is cheap and further extension, if necessary, is possible. Moreover, the bearing capacity of the ground should be adequate so that heavy equipment could be installed.

(v) Nearness to load centres: In order to reduce the transmission cost, the plant should be located near the centre of the load.This is particularly important if dc supply system is adopted.However, if ac the supply system is adopted, this factor becomes relatively less important.It is because ac power can be transmitted at high voltages with consequently reduced transmission cost. Therefore, it is possible to install the plant away from the load centres, provided other conditions are favourable.

(vi) Distance from populated area: As huge amount of coal is burnt in a steam power station, therefore, smoke and fumes pollute the surrounding area. This necessitates that the plant should be located at a considerable distance from the populated areas.

NUCLEAR POWER STATION

FISSILE MATERIALS - A nuclide that is capable of undergoing fission after capturing low-energy thermal (slow) neutrons e.g.- uranium-233, uranium-235, and plutonium-239.

FERTILE MATERIALS - A material, which is not itself fissile (fissionable by thermal neutrons), that can be converted into a fissile material by irradiation in a reactor. There are two basic fertile materials: uranium-238 and thorium-232.

E.g – Conversion of uranium-238 to plutonium

By capturing a neutron, it becomes a nucleus of plutonium-239. ... By capturing a neutron, uranium-238 becomes uranium-239 that rapidly changes by beta radiation into neptunium-239. This neptunium is transformed then by beta radiation, after 3 days on average, into a new nucleus: plutonium-239.

Difference between Uranium-235 and Uranium-238 isotopes

Uranium-235 is one fissile isotope and thus it readily undergoes nuclear fission when bombarded with a thermal neutron

$$_{92}U^{235} + {_0}n^1 \rightarrow {_{92}}U^{236} \rightarrow {_{36}}Kr^{92} + {_{56}}Ba^{141} + 3\,{_0}n^1 + 202.5MeV$$

Uranium (Natural) + Neutron (Thermal) → Uranium (Unstable) → Krypton + Barium + Neutrons (Fast) + Energy/atom

Uranium-238 is not one fissile isotope and thus cannot sustain fission chain reaction. However, U-238 can slowly decay into Plutonium-239 isotope in breeder reactors, which is one fissile isotope.

$$_{92}U^{238} + {_0}n^1 \rightarrow {_{92}}U^{239} \rightarrow {_{93}}Np^{239} + {_{94}}Pu^{239}$$

Uranium-238 (Natural) + Neutron (Fast) → Uranium → Neptunium + Plutonium-239 (Fissile isotope)

$$_{94}Pu^{239} + {_0}n^1 \rightarrow {_{94}}Pu^{240} \rightarrow {_{40}}Zr^{103} + {_{54}}Xe^{134} + 3\,{_0}n^1 + 207.1MeV$$

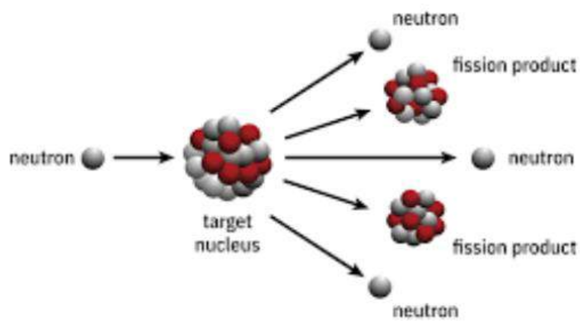
Plutonium (Synthetic) + Neutron (Thermal) → Plutonium (Unstable) → Zirconium + Xenon + Neutrons (Fast) + Energy/atom

www.difference.minaprem.com

NUCLEAR FISSION:In nuclear fission, an unstable atom splits into two or more smaller pieces that are more stable, and releases energy in the process. The fission process also releases extra neutrons, which can then split additional atoms, resulting in a chain reaction that releases a lot of energy. There are also ways to modulate the chain reaction by soaking up the neutrons.

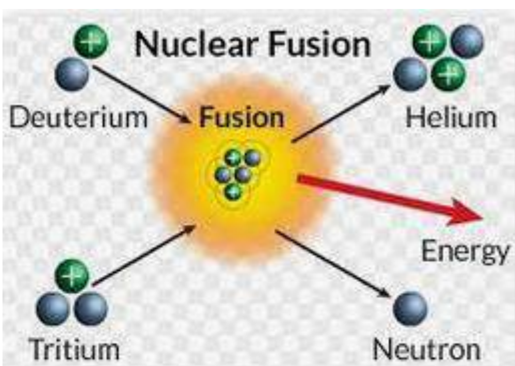
Key Points

- Nuclear fission is a process where the nucleus of an atom is split into two or more smaller nuclei, known as fission products.
- The fission of heavy elements is an exothermic reaction, and huge amounts of energy are released in the process.
- Nuclear fission occurs with heavier elements, where the electromagnetic force pushing the nucleus apart dominates the strong nuclear force holding it together.
- In order to initiate most fission reactions, an atom is bombarded by a neutron to produce an unstable isotope, which undergoes fission.
- When neutrons are released during the fission process, they can initiate a chain reaction of continuous fission which sustains itself.

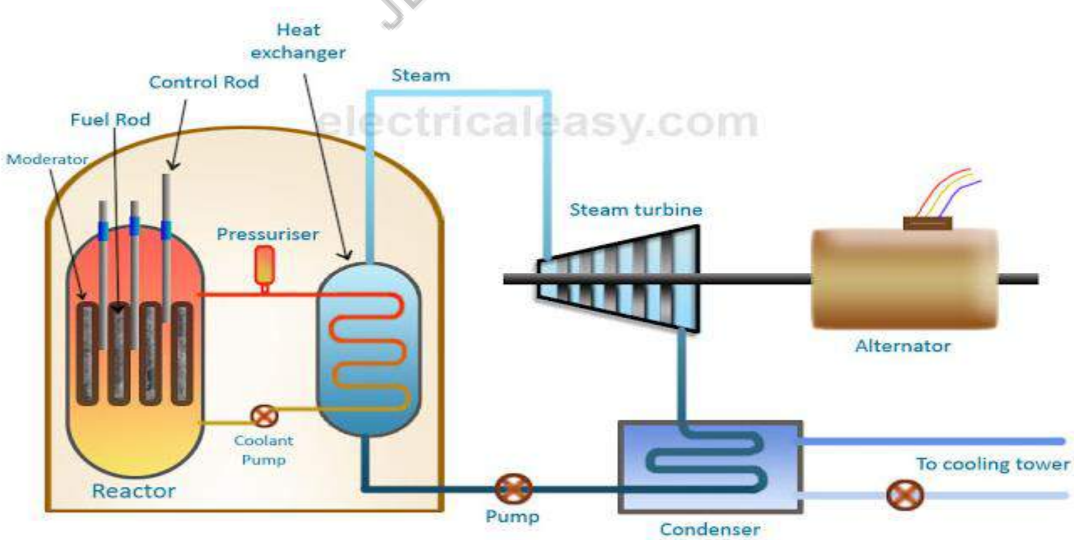


NUCLEAR FUSION:

Nuclear Fusion reactions power the Sun and other stars. In a fusion reaction, two light nuclei merge to form a single heavier nucleus. The process releases energy because the total mass of the resulting single nucleus is less than the mass of the two original nuclei. The leftover mass becomes energy. Einstein's equation ($E=mc^2$), which says in part that mass and energy can be converted into each other, explains why this process occurs.



Basic components of a nuclear power plant



Nuclear Reactor

A nuclear reactor is a special apparatus used to perform nuclear fission. Since the nuclear fission is radioactive, the reactor is covered by a protective shield. Splitting up of nuclei of heavy atoms is called as nuclear fission, during which huge amount of energy is released. Nuclear fission is done by bombarding slow moving neutrons on the nuclei of heavy element. As the nuclei break up, it releases energy as well as more neutrons which further cause fission of neighboring atoms. Hence, it is a chain reaction and it must be controlled, otherwise it may result in explosion. A nuclear reactor consists of fuel rods, control rods and moderator. A fuel rod contains small round fuel pallets (uranium pallets). Control rods are of cadmium which absorb neutrons. They are inserted into reactor and can be moved in or out to control the reaction. The moderator can be graphite rods or the coolant itself. Moderator slows down the neutrons before they bombard on the fuel rods.

Two types of nuclear reactors that are widely used -

1. **Pressurised Water Reactor (PWR) -**
   This type of reactor uses regular water as coolant. The coolant (water) is kept at very high pressure so that it does not boil. The heated water is transferred through heat exchanger where water from secondary coolant loop is converted into steam. Thus the secondary loop is completely free from radioactive stuff. In a PWR, the coolant water itself acts as a moderator. Due to these advantages, pressurised water reactors are most commonly used.
2. **Boiling Water Reactor (BWR) -**
   In this type of reactor only one coolant loop is present. The water is allowed to boil in the reactor. The steam is generated as it heads out of the reactor and then flows through the steam turbine. One major disadvantage of a BWR is that, the coolant water comes in direct contact with fuel rods as well as the turbine. So, there is a possibility that radioactive material could be placed on the turbine.

Heat exchanger

In the heat exchanger, the primary coolant transfers heat to the secondary coolant (water). Thus water from the secondary loop is converted into steam. The primary system and secondary system are closed loop, and they are never allowed to mix up with each other. Thus, heat exchanger helps in keeping secondary system free from radioactive stuff. Heat exchanger is absent in boiling water reactors.

Steam Turbine

Generated steam is passed through a steam turbine, which runs due to pressure of the steam. As the steam is passed through the turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator through a rotating shaft.

Condenser

The steam coming out of the turbine, after it has done its work, is then converted back into water in a condenser. The steam is cooled by passing it through a third cold water loop.

NUCLEAR REACTORS

An apparatus in which a nuclear-fission chain reaction can be initiated, sustained, and controlled, for generating heat or producing useful radiation.

Mechanism of heat production: The main job of a reactor is to house and control nuclear fission—a process where atoms split and release energy.

Reactors use uranium for nuclear fuel. The uranium is processed into small ceramic pellets and stacked together into sealed metal tubes called fuel rods. Typically more than 200 of these rods are bundled together to form a fuel assembly. A reactor core is typically made up of a couple hundred assemblies, depending on power level.
Inside the reactor vessel, the fuel rods are immersed in water which acts as both a coolant and moderator. The moderator helps slow down the neutrons produced by fission to sustain the chain reaction.
Control rods can then be inserted into the reactor core to reduce the reaction rate or withdrawn to increase it.
The heat created by fission turns the water into steam, which spins a turbine to produce carbon-free electricity.

Classification of Nuclear Reactors:

Nuclear reactors may be classified in several ways i.e., on basis of their applications, type of fission, fuel used, state of fuel, fuel cycle, arrangement of fissile and fertile material, arrangement of fuel and moderator, moderator material, cooling system employed, coolant used etc.

I. According to the applications the reactors are classified as:

(a)Research and Development Reactors:
These reactors are used for testing new reactors designs and research.
(b)Production:
These reactors are used for converting fertile materials ito fissile materials.
(c) Power:
These reactors are used for generation of electrical energy.

II. According to the type of fission the reactors are classified as fast reactors, slow reactors and intermediate reactors.
In fast reactors the fission is caused by fast neutrons whereas in thermal reactors it is caused by slow or thermal neutrons. Initially all the neutrons are fast when emitted in a reactor and in thermal reactor their speed is reduced with the help of moderator. For natural uranium, graphite moderated reactor, the ratio of moderator to fuel volume is between 50 and 80; for heavy water moderated reactor this ratio lies between 20 and 40 while for enriched uranium light water moderated reactor this ratio is between 1.5 and 2.5.
Thus the reactor core of a thermal reactor is very much larger than that of a fast reactor which has no moderator. Obviously heat energy generated per unit volume of the reactor core in a thermal reactor is very much less than in afast reactor with the result that the cooling problems are much simpler in a thermal reactor.
In intermediate reactors, most of fission events are caused by neutron in the process of slowing down. Such systems are very difficult to design because the resonance cross- section structure in this energy range. Slightly enriched fuels are used in these reactors.
Advantages of fast breeder reactors:

1. Fast reactor can convert more fertile material to fissile material with the result that the net fuel consumption for such reaction is much less. As a matter of fact more fissile material could be produced in a fast reactor than would be consumed by it.
2. These reactors are small and compact and so easier to shield.
3. Since absorption cross sections are small, any structural material can be used for reactor core.

Disadvantages:

1. Heat transfer and cooling problem in the core are complicated due to high powr density(thermal power to core volume ratio in Kw/m^3).
2. High fuel loading requirement.
3. The core of a fast reactor requires high enrichment(above 10% of fissile material).
4. Radiation damage(embrittlement and swelling) of the structural material in the core due to fast or energy neutron.
5. The fast neutron having much shorter "neutron lifetimes" than thermal neutrons can cause some control problems under certain conditions.

The advantages and disadvantages of thermal reactors are enumerated below.

Advantages:

1. Ease of control because of relatively low power densities and longer neutron life times.
2. Greater inherent safety.
3. Low fuel loading.

Disadvantages:

1. Very much restricted choice of fuel when uranium is used as fuel.
2. Higher size and weight of reactor per unit power due to low power density.
3. More fissile material consumption.
4. Requirement of small absorption cross section materials.

III. According to the type offuel used the reactors may be classified as:

1. Natural uranium
2. Enriched uranium
3. Plutonium

IV. According to the state of fuel reactor can be classified as:

1. Solid
2. Liquid

V. According to the fuel cycle the reactors may be classified as:

1. Burner (Thermal) reactor : Such reactors are designrd for generating heat without any recovery of converted fertile materials.
2. Converter reactor: Such reactor convert fertile material into fissile material different from the one initially fed into the reator core. We know that natural uranium as the nuclear fuel U-238 is converted into plutonium.
3. Breeder reactor: Such reactors convert fertile material into fissile material, which is similar to one initially supplied to the reactor core. A breeder reactor is one in which the fertile material is converted to fissile material at a higher rate than at which the fissile material is consumed.

VI. As per arrangement of fissile and fertile material the reactors may be classified as:

1. One region (fissile and fertile material mixed)
2. Two region (fissile and fertile material separate).

VII. According to the arrangement of fuel and moderator the reactors may be classified as:

1. Homogenous
2. Heterogenous

In homogeneous reactors, the nuclear fuel and the moderator represent a uniform mixture in the fluid form, including gases, liquids and slurries whereas in the heterogeneous reactors, separate fuel slugs or rods are inserted in the moderator in some regular arrangement forming a so called lattice.

In a homogeneous reactor, the mixture of nuclear fuel and moderator is circulated from the reactor to an external heat exchanger, then to a pump and then back to the reactor. The major drawback of homogeneous reactor is that the fuel solution also contains the highly radioactive fission products. Any leakage or component failures in the primary-reactor coolant system are extremely difficult to repair because of the presence of these fission products.

Otherwise, a homogeneous reactor has some significant advantages such as excellent in cor heat transfer because of generation of the fission energy in the fuel-coolant solution itself. Also, the reactor fuel can be added, removed and reprocessed during reactor operation without shutting it down. Most of the present reactors are heterogeneous type.

VIII. On the basis of moderator material used the reactors may be classified as:

1. Heavy water
2. Graphite
3. Ordinary graphite
4. Beryllium
5. Organic reactors

The most commonly used moderator materials are graphite, ordinary or natural water and heavy water.

Graphite has got higher atomic weight than water and, therefore, the reactors employing graphite as moderator will be very bulky. Natural water gives a small and compact reactor, but the reactor would have to be pressurized and use enriched fuel. With heavy water, ordinary natural fuel can be used but it is very expensive.

IX. On the basis of coolant used the reactors may be classified as:

1. Gas
2. Water
3. Heavy water
4. Liquid metal reactors

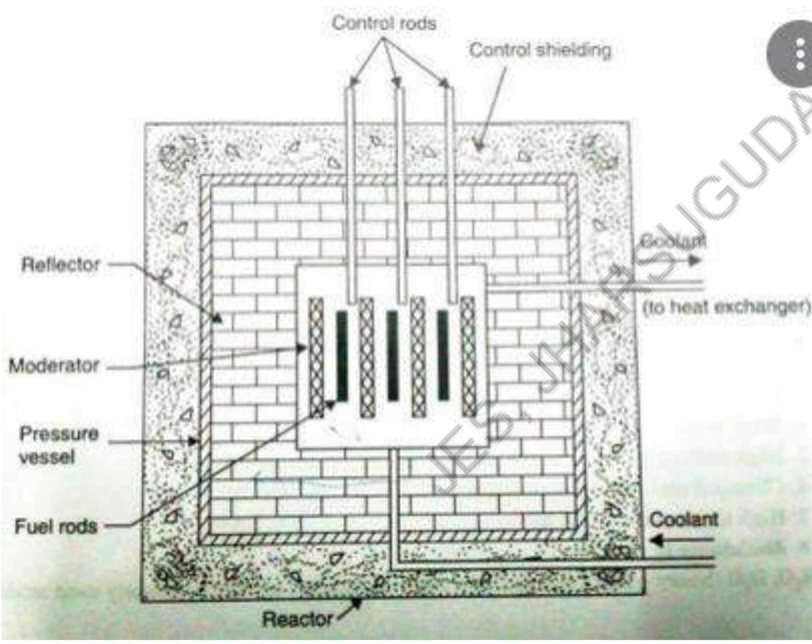
X. On the basis of cooling system employed the reactors may be classified as:

1. Direct and
2. Indirect reactors

In direct system of cooling, the fuel is in the liquid form and it acts as a coolant. It is circulated through the reactor core and a heat exchanger in which its heat is transferred to the circulating water to produce steam. In this system reactor may be either of the aqueous homogeneous type or liquid metal fuelled type and the heat exchanger should be located within the biological shield because the circulating liquid fuel is highly radioactive.

In indirect system of cooling, the coolant may be a gas, water(light or heavy), a liquid metal or an organic coolant. In this system of cooling, coolant is pumped through pipes.

COMPONENTS OF NUCLEAR REACTOR



1. Reactor Core- It consists of fuel elements, control rods, coolant, moderator and pressure vessels. Cores generally have shapes of right circular cylinders with diameters ranging from .5 to 15 metres. Fuel rods made of uranium rods clod in thin sheath of stainless steel, zirconium or aluminium.

2. Reflector- It is placed round the core, to reflect back some of the neutrons that leak out from core surface.

3. Control Rods It is made up of heavy mass element.It simply absorb the neutrons so that it can either maintain or stop a reaction. Examples-Cadmium,lead etc.

It has following purposes- 1.For starting the reactor. 2.For maintaining at that level. 3.For shutting the reactor down under normal or emergency conditions.

 For starting the reactor- To start a reactor,a neutron from a source is ejected through thermal means and the control rods are taken upwards so that the control rods can not disturb the reaction. Hence neutron hits the fuel rods,break it into lighter nuclie,energy is released,number of neutron keeps on increasing since K will be greater than 1 for this time period and hence reaction starts and its rate also increases.

 For maintaining the reaction at constant level When rate of reaction achieves a permissible value then control rods are inserted between the fuel rods in such away that K becomes equal to 1. Hence the rate of reaction achieves a finite constant value.

 For shutting down the reactor To shut down the reactor either in normal or emergency condtions,the control rods are inserted in such away that K becomes less than 1. Hence the number of neutrons keeps on decreasing,ie rate of reaction decreases,hence the reaction stops after a certain interval of time.

 4. Moderator Function:To slow down neutrons from high velocities and hence high energy level which they have on being released from fission process so that probability of neutron to hit the fuel rods increases.
Main moderator used:
1.Water H_2O.
2.Heavy water D_2O.
3.Graphite.
4.Beryllium.

 Properties of Moderator

- High slowing down power
- Non corrosiveness High MP for solids and low for liquids
- Chemical and radiation stability
- High thermal stability
- D2O is best for moderator.

 5. Coolant Function- Coolant is used to remove intense heat from the produced in the reactor and that heat can be transferred to water in a seprate vessel which is converted into steam and runs the turbine.

Characteristics-
1.Low Melting point
2.high Boiling point
3.chemical and radiation stability
4.Low viscosity
5.Non toxicity
6.Non corrosiveness

 Commonly used Coolant

1. Hg
2. He
3. CO_2
4. H_2O

Mostly used gaseous Coolant is CO_2

 6.Shielding Shielding is required to protect the working men from the harmful effects of the radiation. In fission,alpha particles,beta particles,gamma rays,slow and fast neutrons are formed in which gamma rays and fast neutrons are of main significance.

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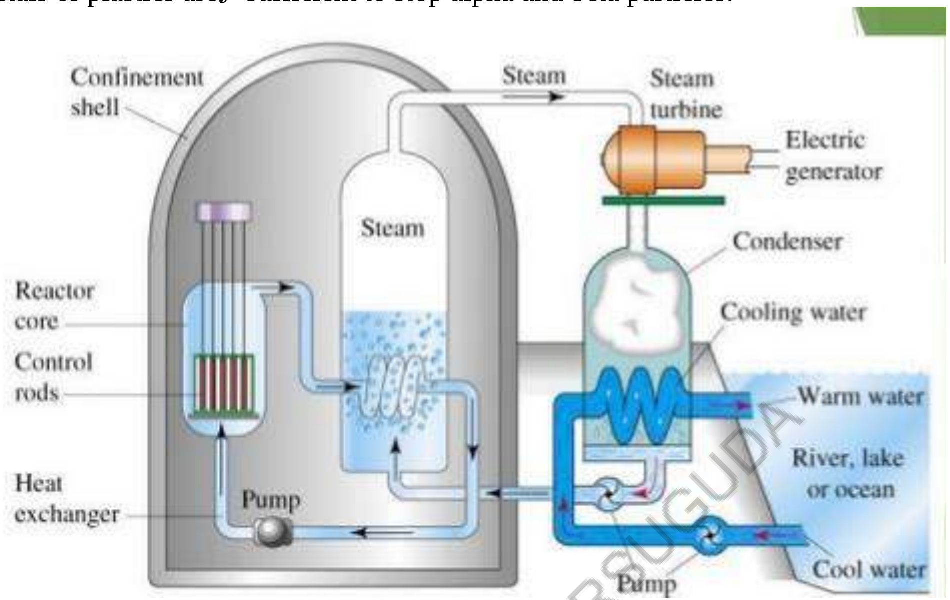

COMPARISION OF NUCLEAR AND THERMAL POWER PLANT

The nuclear power plant and the fossil thermal power plant both use steam to convert the heat or thermal energy to mechanical rotation to rotate the generator to produce electricity. Only the heat source is different. In a nuclear plant, the heat source is from the nuclear reaction whereas in a thermal power plant it is from the combustion of coal.

The difference is in the inlet steam parameters to the turbine in a nuclear plant. Thermal power plants use steam at superheated conditions. In nuclear plants, the steam is at saturated conditions and at a lower pressure. This is due to the inherent design limitations in the nuclear reactors.

In fossil power plants the inlet steam parameters are typically temperatures of 540 º C to 580 º C and pressures of 170 bar or even higher. In addition, there is additional heating in the form of re-heating. In a nuclear plant, the ratings are typically saturated steam at 78 bar, which is steam temperature of 298 º C. The nuclear plant uses a ‘wet steam turbine’.

Increased Steam Flow.

The reduced inlet steam parameters in the nuclear plant results in lower thermal efficiencies. Nuclear plants operate at lower thermal efficiencies , lower by more than 10 %. The energy of steam per unit mass entering the turbine is also less. This results in a very high steam flow for the same MW output, almost double that of fossil power plants.

The configurations of the turbines change due to this. The economics of scale requires the nuclear plants to be in the range of 600 MW to 1000 MW resulting in very big Turbines.

Wet Steam

Nuclear steam turbines are ‘wet steam turbines’.

Since the steam is at saturated conditions, after each stage expansion the steam gets wetter. The water particles result in lower efficiency of the turbine. This results in erosion damage to the blades. In addition, this results in vibrations and stress in the last stage. To overcome this nuclear steam turbines use special design of blades and flow paths.

Moisture separators located in the steam path at exit of HP / IP and in the cross under pipes reduce the undesirable effects of the moisture in the steam. Moisture Separator Reheaters also are used. These use extracted steam to aid in moisture removal.

No Reheating

Nuclear steam cycles do not have Reheating as in fossil units. This also reduces the cycle efficiency.

Even with the much lower thermal efficiency, Nuclear power is feasible due to low unit cost of fuel.

DISPOSAL OF NUCLEAR WASTE

- Radioactive wastes are stored so as to avoid any chance of radiation exposure to people, or any pollution.
- The radioactivity of the wastes decays with time, providing a strong incentive to store high-level waste for about 50 years before disposal.
- Disposal of low-level waste is straightforward and can be undertaken safely almost anywhere.
- Storage of used fuel is normally under water for at least five years and then often in dry storage.
- Deep geological disposal is widely agreed to be the best solution for final disposal of the most radioactive waste produced.

The disposal methods for nuclear waste most used is simple storage. For example, dry cask storage uses steel cylinders along with inert gas or water to seal and store radioactive waste from spent fuel pool. [5] The steel cylinder is usually further placed in a concrete cylinder. These cylinders serve as radiation shield for the nuclear waste, stopping the radiation from reachin the outside. This is a relatively inexpensive way for storing radioactive waste. It doesn't require special location and transportation. The radioactive waste can be easily stored at a on-site reactor facility or adjacent to the source reactor. In addition, it is convenient to retrieve the waste from those storage cylinders for future reprocessing.

The other storage methods involve the selection of appropriate geologic location for the storage of high level radioactive waste. In this method, deep and stable geologic formations were selected to store the nuclear waste for long term. [6] In this process, large and stable geologic locations are first located and then excavated to form long tunnels (~kilometers) under the surface using conventional mining technology. The spent fuel and radioactive waste are then placed in the tunnels. Since the geologic formations chosen in this method are far from human population centers, the nuclear wastes are expected to be stably isolated from human living environment for the long term. This technique is still under investigation and development. Several countries in the world (e.g. England and France) were on the way of using this geologic disposal technique. However, there are still many concerns about this geologic disposal technique, because the stored nuclear waste has potential to leak into the environment if any huge geologic changing occurs (*e.g.* an earthquake). Moreover, even very low leakage or migration of nuclear waste may result in a huge disaster because the half-lives of the nuclear waste are so long. In this case, the nuclear waste would become a human catastrophe. Therefore, many countries in the world still don't agree with the using of this deep geologic disposal technique.

A similar technique is storaging the nuclear waste under then ocean. Essentially this is a kind of geologic disposal. [7] However, considering that the nuclear waste would leak and migrate more easily in the ocean, this technique has the higher risk for nuclear waste spreading. Moreover, these ocean disposal may be more difficult to monitor for leakage of the nuclear waste, making the control and management of the nuclear waste further challenging.

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List of Nuclear Power Plants In India

Given below is the list of 7 sites of Nuclear Power Plants in India. Candidates can download the List of Nuclear Power Plants in India PDF given both at the top and bottom of this article.

Nuclear Power Plants in India – Operational			
Name Of Nuclear Power Station	**Location**	**Operator**	**Capacity**
Kakrapar Atomic Power Station – 1993	Gujarat	NPCIL	440
(Kalpakkam) Madras Atomic Power Station – 1984	Tamil Nadu	NPCIL	440
Narora Atomic Power Station- 1991	Uttar Pradesh	NPCIL	440
Kaiga Nuclear Power Plant -2000	Karnataka	NPCIL	880
Rajasthan Atomic Power Station – 1973	Rajasthan	NPCIL	1,180
Tarapur Atomic Power Station – 1969	Maharashtra	NPCIL	1,400
Kudankulam Nuclear Power Plant – 2013	Tamil Nadu	NPCIL	2,000

- Nuclear power is the fifth-largest source of electricity in India after thermal, hydroelectric and renewable sources of electricity.
- Presently, India has 22 nuclear power reactors operating in 7 states, with an installed capacity of 6780 MegaWatt electric (MWe).
- 18 reactors are Pressurised Heavy Water Reactors (PHWRs) and 4 are Light Water Reactors (LWRs).

- Nuclear Power Corporation of India Limited -NPCIL based in Mumbai is a government-owned corporation of India that is responsible for the generation of electricity through nuclear power.
- NPCIL is administered by the Department of Atomic Energy, Government of India.

Introduction: *Diesel Power station*

A Diesel power station(also known as Stand-by power station) uses a diesel engine as prime mover for the generation of electrical energy.
This power station is generally compact and thus can be located where it is actually required. This kind of power station can be used to produce limited amounts of electrical energy. In most countries these power stations are used as emergency supply stations.

Operation

The diesel burns inside the engine and the combustion process moves a fluid that turns the engine shaft and drives the alternator. The alternator in turn, converts mechanical energy into electrical energy.
This type of electricity generating power station will probably be used a long time into the future, due to a need for reliable stand-by electrical source for emergency situations.
However, diesel power plants emit green house gases that pollute the environment and also require frequent servicing.

Advantages	Disadvantages
Simple design & layout of plant	
Occupies less space & is compact	Plant does not work efficiently under prolonged overload conditions
Can be started quickly and picks up load in a short time	Generates small amount of power
Requires less water for cooling	Cost of lubrication very high
Thermal efficiency better that of Steam Power plant of same size	Maintenance charges are generally high
Overall cost is cheaper than that of Steam Power plant of same size	.
Requires no Operating staff	.
No stand-by losses	.

CLASSIFICATION OF I.C ENGINES:

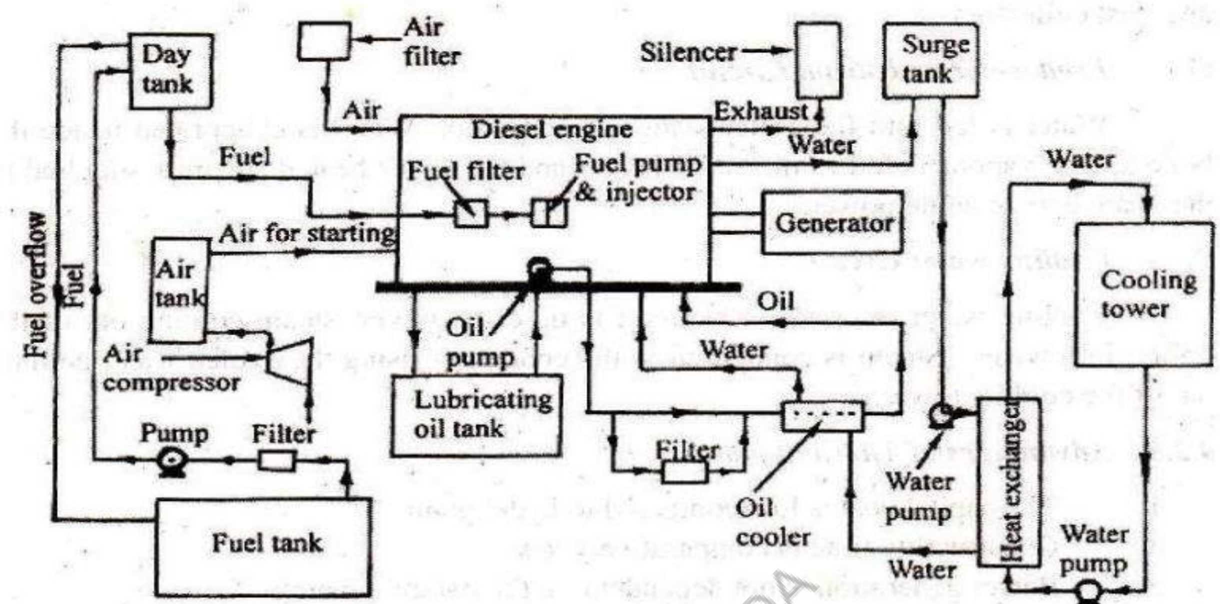
The internal combustion engine can be classified in the following ways:

1. According to the type of fuel used
   a)Petrol engines, b)Diesel engines, c)Gas engines.
2. According to the method of ignition of fuel
   a)Spark ignition engines, and b)Compression ignition engines
3. According to the number of strokes per cycle:
   a)Four stroke cycle engines, and b)Two stroke cycle engines
4. According to the cycle of operation
   a)Otto cycle engines, b)Diesel cycle engines, and c)Dual cycle engines.
5. According to the speed of the engine
   a)Slow speed engines, b)Medium speed engines, and c)High speed engines.
6. According to the cooling system
   a)Air cooled engines and b)Water cooled engines.
7. According to the method of fuel injection
   a)Carburettor engines, and b)Air injection engines.
8. According to the number of cylinders
   a)Single cylinder engines, and b)multi cylinder engines.

Selection of Site for a Diesel Power Station:

1. Near to Load Center: As far as possible the plant should be installed near to load center, to reduce transmission & distribution cost of electrical energy.
2. Availability of Land: For erection of diesel power plant, land should be available near to load center at low cost.
3. Availability of Water: The soft water is freely available for the purpose of cooling.
4. Foundations: As we know that, the diesel engines or a machine produces vibrations. So provide good foundation to erect the diesel engine.
5. Fuel Transportation: The diesel plant is far away from fuel mines. So to provide fuel to the plant arrange good transportation facility like road, rail etc.
6. Local Conditions: For increasing the demand of power & future expansion space available.
7. Noise Pollution: The plant should away from populated areas, because it produces noise

Components of Diesel power plant



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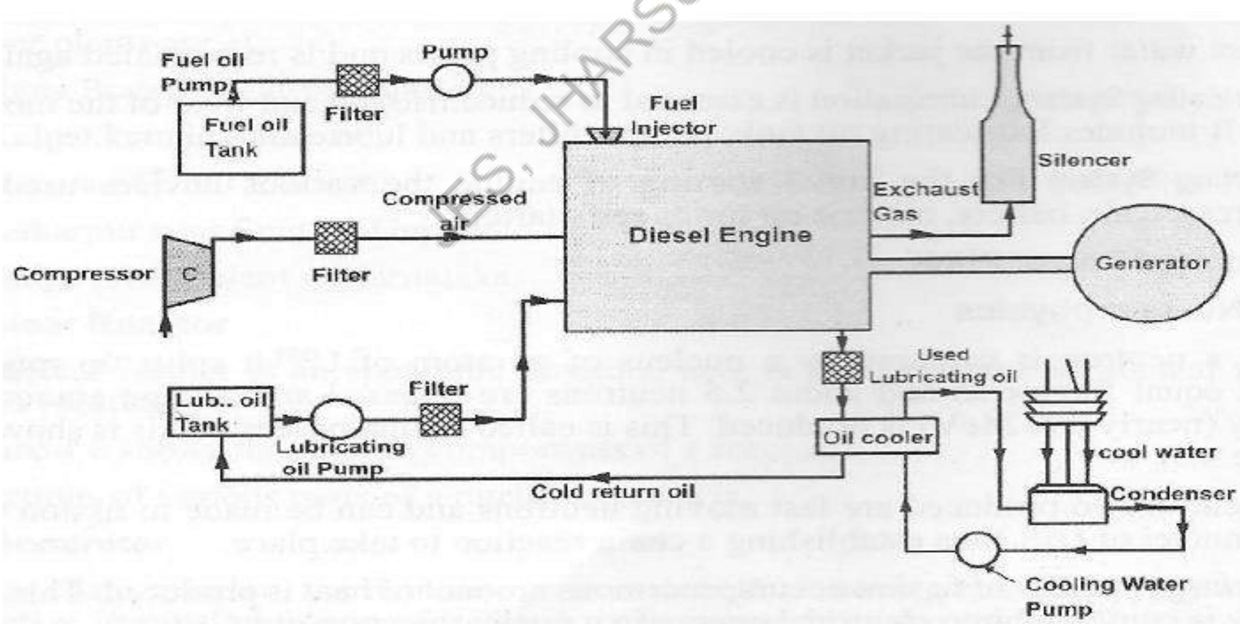


Main Components of Diesel Electric Power Plant: The essential components of a diesel electric power plant are as follow:

1. Diesel Engine

2. Engine Fuel Supply System

3. Engine Air Intake System

4. Engine Exhaust System

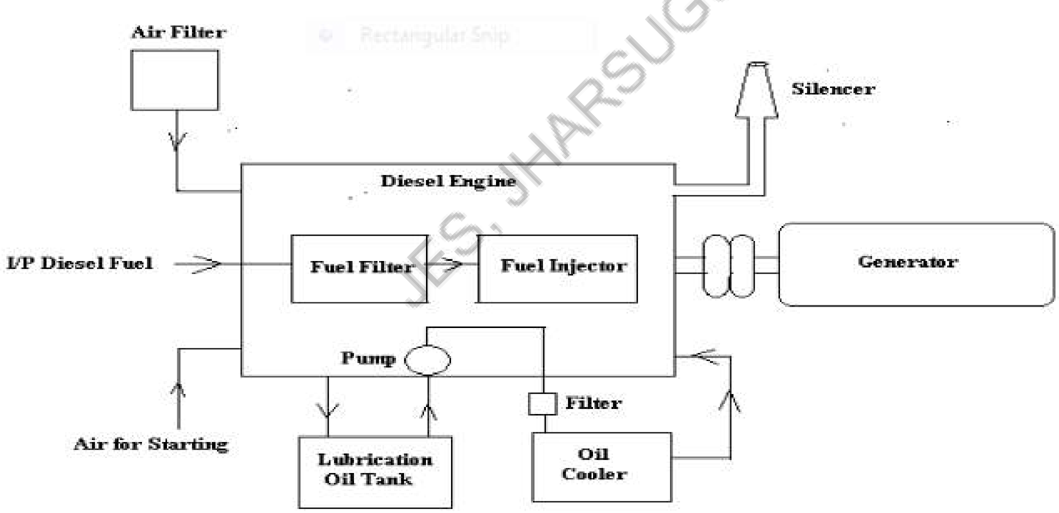
5. Engine Cooling System

6. Engine Lubrication System.

7. Engine Starting System.

8. Governing Systems

Diesel Engine

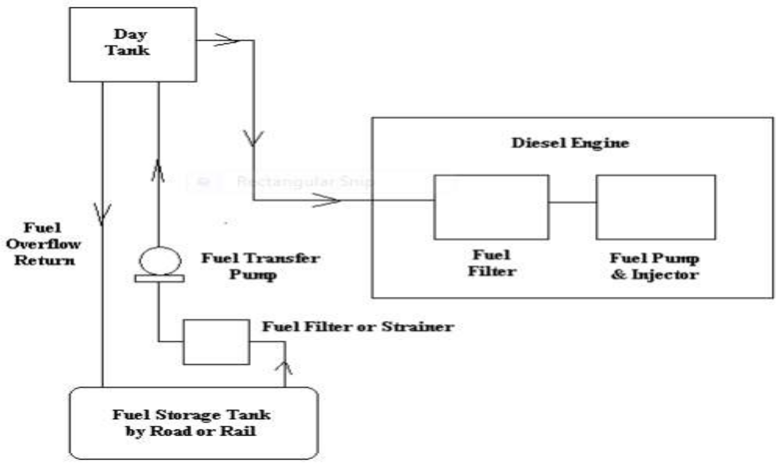


It is the main components used in diesel electric power plant for developing mechanical power. This mechanical power we use to run the generator & produce electrical energy. For producing the electrical energy the diesel engine is mechanically coupled to generator. When the diesel fuel burning inside the engine, its start to produce a mechanical power. The combustion of diesel fuel produces increased temperature & pressure inside the engine. Due to this pressure gases are formed, this gas pushes the piston inside the diesel engine, and then mechanical power is produced. With the use of this mechanical power the shaft of diesel engine starts rotating.

Engine Fuel Supply System:

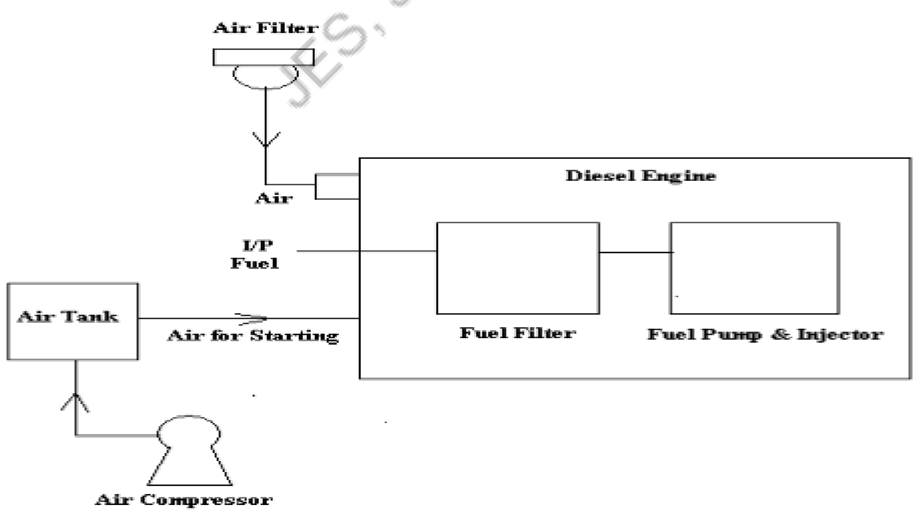
It consists of Fuel Storage Tank, Fuel Filter or Strainer, Fuel Transfer Pump, Day Tank, Heaters & Connecting Pipes.

First up all with the help of transportation facility available (road, rail etc.) the diesel fuel stored in storage tank. Then this diesel fuel transfer to day tank, the function of day tank is how much quantity of diesel required for 24 hours is store. If the day tank is full or overflow occurs, then excessive diesel returned to storage tank. The filter or strainer is used to purify diesel. With the help of fuel transfer pump the diesel is transfer to day tank.



Engine Air-Intake System

This System includes air filters, air tank, compressor & connecting pipes. The air filters are used to supply the fresh air to diesel engine for the purpose of combustion. Engine required fresh air because, if dust particles in the air entered into the engine will cause disastrous effect to valve, cylinder & pistons. The compressor or Supercharger is used to increase pressure of the air supplied to the engine. This will helps to increase the output power.



Engine Exhaust System:

These systems consist of silencers & connecting ducts. As the temperature of the exhaust gases is sufficiently high, it is used for heating the fuel oil or air supplied to the diesel engine. The exhaust gas is removed from engine, to the atmosphere by means of an exhaust system. A silencer is normally used in this system to reduce noise level of the engine.

Engine Cooling System

The Diesel Engine Cooling System Consist of coolant pumps, water cooling towers or spray pond, water treatment or filtration plant & Connecting Pipe Works.

The heat produced due to internal combustion, drives the engine. But some parts of this heat raise the temperature of different parts of the engine. High temperature may cause permanent damage to the machine. Hence, it is essential to maintain the overall temperature of the engine to a tolerable level. Cooling system of diesel power station does exactly so.

The cooling system is required to carry heat from diesel engine to keep its temperature within safe limits. The water pump circulates water to cylinder of diesel engine to carry away the heat. The cooling tower is used for the same water reused.

The cooling system requires a water source, water pump and cooling towers. The pump circulates water through cylinder and head jacket. The water takes away heat from the engine and it becomes hot. The hot water is cooled by cooling towers and is re-circulated for cooling.

The cooling system can be classified into two types:

1.Open Cooling System: A Plant near the river may utilize the river water for cooling & discharging again the hot water into river. This type of cooling system is known as open cooling system.

2.Closed Cooling System: The Cooling Water is circulated again & again and only water lost due to leakage, evaporation etc. is made up by taking make up water from supply source

Engine Lubrication System:

Engine lubrication system consists of lubricating oil pump, oil tanks, filters, coolers, purifiers & connecting pipes. This system provides lubricating oil to moving parts of the system to reduce the friction between them wear & tear of the engine parts.

This system minimizes the water of rubbing surface of the engine. Here lubricating oil is stored in main lubricating oil tank. This lubricating oil is drawn from the tank by means of oil pump. Then the oil is passed through the oil filter for removing impurities. From the filtering point, this clean lubricating oil is delivered to the different points of the machine where lubrication is required the oil cooler is provided in the system to keep the temperature of the lubricating oil as low as possible.

It is then cooled through heat exchanger by means of cold water and then it is fed to the engine.

Engine Starting System:

The function of starting system is to start the engine form stand still or cold conditions by supplying compressed air.

For starting a diesel engine, initial rotation of the engine shaft is required. Until the firing start and the unit runs with its own power. For small DG set, the initial rotation of the shaft is provided by handles but for large diesel power station. Compressed air is made for starting.

This system includes storage compressed air tank, self starter, auxiliary engines & electrical motors (battery) etc

1. Starting of Small Engine: Small sets or small capacity of diesel engines are started manually.

2. Starting with the help of Auxiliary Engine: When it is started by auxiliary engine, the auxiliary engine is disengaged by the main engine & started by hand. When it is warmed up, it is geared with the main engine so that it will start to rotate. After that within, few seconds auxiliary engine disengaging.

3. Starting with the help of batteries: To start the electrical motor batteries are used, the motor is geared with diesel engine, it will start rotating with the motor & will start in few seconds & as it picks up the speed the motor gets disengaged automatically. In some cases the motor works as a generator, this will further helps to charge the batteries.

4. Starting with the help of compressed air: A large capacity (above 75kW) capacity diesel engines are started with the help of compressed air. Diesel engines are started with the help of compressed air following procedure adopted:

1. First up all open the compressed air valve, then starting lever operated.

2. First up all air should be cut off in first combustion. Then open ventilating valve. Start the engine after two or three revolutions

Engine Governing System:

The function of the governing system is to maintain the speed of the engine constant irrespective of the load of the plant.This is generally done by varying fuel supply to the engine according to load.

PERFORMANCE OF DIESEL ELECTRIC POWER STATION

The performance of the diesel engine focuses on the power and efficiency. The engine varies with parameters of the enginelikepiston speed, air-fuel ratio, compression ratio inlet air-pressureand temperature. The two usual conditions under which I.C. engines are operated are:

(a)constant speed with variable load, and
(b) variable speed with variable load.
The first situation is found in a.c. generator drives and the second one in automobiles, railway engines and tractors etc. A series of tests are carried out on the engine to determine its performance characteristics, such as: indicated power (I.P.), Brakepower (B.P.), Frictional Power (F.P.), Mechanical efficiency (η_m), thermal efficiency, fuel consumption and also specific fuel consumption etc. The measurement of these quantities is discussed below.

Indicated Mean Effective Pressure (IMRP)

In order to determine the power developed by the engine, the indicator diagram of engine should be available. From the area of indicator diagram it is possible to find an average gas pressure which, while acting on piston throughout one stroke, would account for the network done. This pressure is called indicated mean effective pressure (IMEP).

Indicated Horse Power(IHP)

The indicated horse power (IHP) of the engine can be calculated as follows

$$\text{IHP} = \frac{P_m LANn}{4500 \times k}$$

Pm = IMEP, kg/cm^2
L= length of strokes, metres
A = Piston areas, cm^2
N = Speed, RPM,
n= number of cylinders, and
k = 1for two stroke engine
= 2 for four stroke engine

Brake Horse Power (BHP)
Brake horse power is defined as the net power available at the crankshaft. It is found by measuring the output torque with a dynamometer.

$$\text{BHP} = \frac{2\pi NT}{4500}$$

T= Torque

Frictional Horse Power(FHP)
The difference of IHP and BHP is called FHP. It is utilized in overcoming frictional resistanceof rotating and sliding parts of the engine.

FHP= IHP–BHP

Indicated Thermal Efficiency(η_i)
It is defined as the ratio of indicated work to thermal input.

$$\eta_i = \frac{IHP \times 4500}{(W \times C_v \times J)}$$

W= Weight of fuel supplied, kg per minute,
Cv= Calorific value of fuel oil,kcal/kg,
And J= Joules equivalent = 427.

Brake Thermal Efficiency (Overall Efficiency)
It is defined as the ratio of brake output to thermal input.

$$\eta_b = \frac{BHP \times 4500}{(W \times C_v \times J)}$$

Mechanical Efficiency(η_m)
It is defined as the ratio of BHP to IHP. Therefore,

$$\eta_m = \frac{BHP}{IHP}$$

Only 34 per cent of the energy supplied to the diesel electric power plants in the form of fuel is converted into useful work, remaining is lost in cooling water (about 30%), through exhaust gases (about 25%) and in radiation, friction etc. (11%). Thus the full-load thermal efficiency of a diesel power plant comes out to be about 34%. At part load, the thermal efficiency decreases appreciably and specific fuel consumption increases, as shown in Fig. So part-load operation of diesel power plants is not economical. Specific fuel consumption at full load is roughly 0.23 kg per kWh.

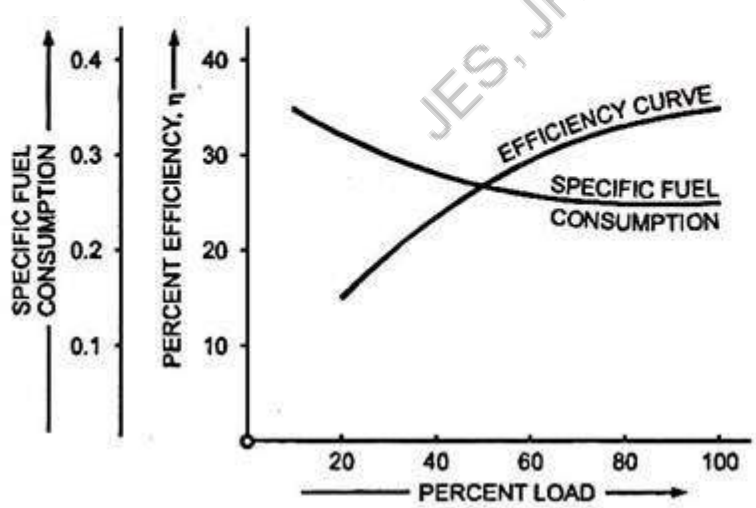


Fig. 5.3. ***Performance Curves of Diesel Power Plant***

What is Hydroelectric energy?

Hydroelectric energy is the most commonly used renewable energy source in the world. Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation – 3,427 terawatt-hours of electricity production in 2010, and is expected to increase about 3.1% each year for the next 25 years. Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use.According to the 2019 Hydropower Status Report, hydroelectricity gave us a whopping 21.8 GW of energy and grew by 9% over the year.

Advantages of Hydroelectric Energy

1. Renewable

Hydropower is completely renewable, which means it will never run out unless the water stops flowing. As a result, hydro plants are built to last. In some cases, equipment that was built to last 25 years is still operational after double the amount of time has passed.

2. Emission Free

The creation of hydroelectricity does not release emissions into the atmosphere. This is, of course, the biggest appeal of any renewable energy source.

3. Reliable

Hydropower is, by far, the most reliable renewable energy available in the world. Unlike when the sun goes down or when the wind dies down, water usually has a constant and steady flow 24/7.

4. Adjustable

Since hydropower is so reliable, hydro plants can actually adjust the flow of water. This allows the plant to produce more energy when it is required or reduce the energy output when it is not needed. This is something that no other renewable energy source can do.

5. Create Lakes

Lakes can be used for recreational purposes and can even help draw in tourists. Look no further than Lake Mead. It was created as a result of the Hoover dam and brought in over 7.5 million visitors in 2018. This can give nearby towns a huge boost economically.

6. Faster Developed Land

Since hydro dams can only be built in specific locations, they can help develop the land for nearby towns and cities. This is because it takes a lot of equipment to build a dam. To transport it, highways and roads must be built, which helps open new paths for rural towns.

Disadvantages of Hydroelectric Energy

1. Impact on Fish

To create a hydro plant, a running water source must be dammed. This prevents fish from reaching their breeding ground, which in turn affects any animal that relies on those fish for food.

As the water stops flowing, riverside habitats begin to disappear. This can even remove animals from accessing water.

2. Limited Plant Locations

While hydropower is renewable, there are limited places in the world that are suitable for plant construction. On top of this, some of these places are not close to major cities that could fully benefit from the energy.

3. Higher initial Costs

While no power plant is easy to build, hydro plants do require you to build a dam to stop running water. As a result, they cost more than similarly sized fossil fuel plants.

Although, they will not need to worry about purchasing fuel later on. So it does even out over the long-term.

4. Carbon and Methane Emissions

While the actual electricity generation in the plant does not produce emissions, there are emissions from the reservoirs they create. Plants that are at the bottom of a reservoir begin to decompose. And when plants die, they release large quantities of carbon and methane.

5. Susceptible to Droughts

While Hydropower is the most reliable renewable energy available, it is dependent on the amount of water in any given location. Thus, the performance of a hydro plant could be significantly affected by a drought. And as climate change continues to heat up or planet, this could become more common.

6. Flood Risk

When dams are built at higher elevations, they pose a serious risk to any town nearby that is below it. While these dams are built very strong, there are still risks.

Hydro Is Still Growing

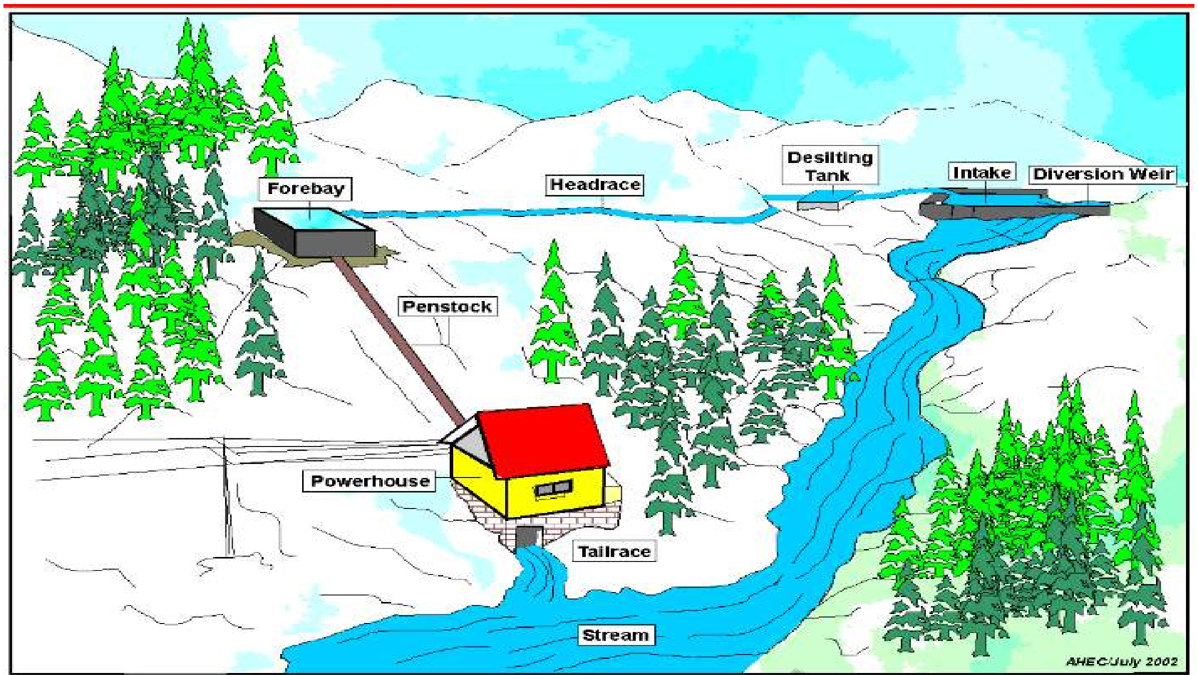
Hydro has been steadily growing as the world begins to ditch its reliance on fossil fuels for energy. It's worth noting that there are many pros and cons of hydroelectric energy.

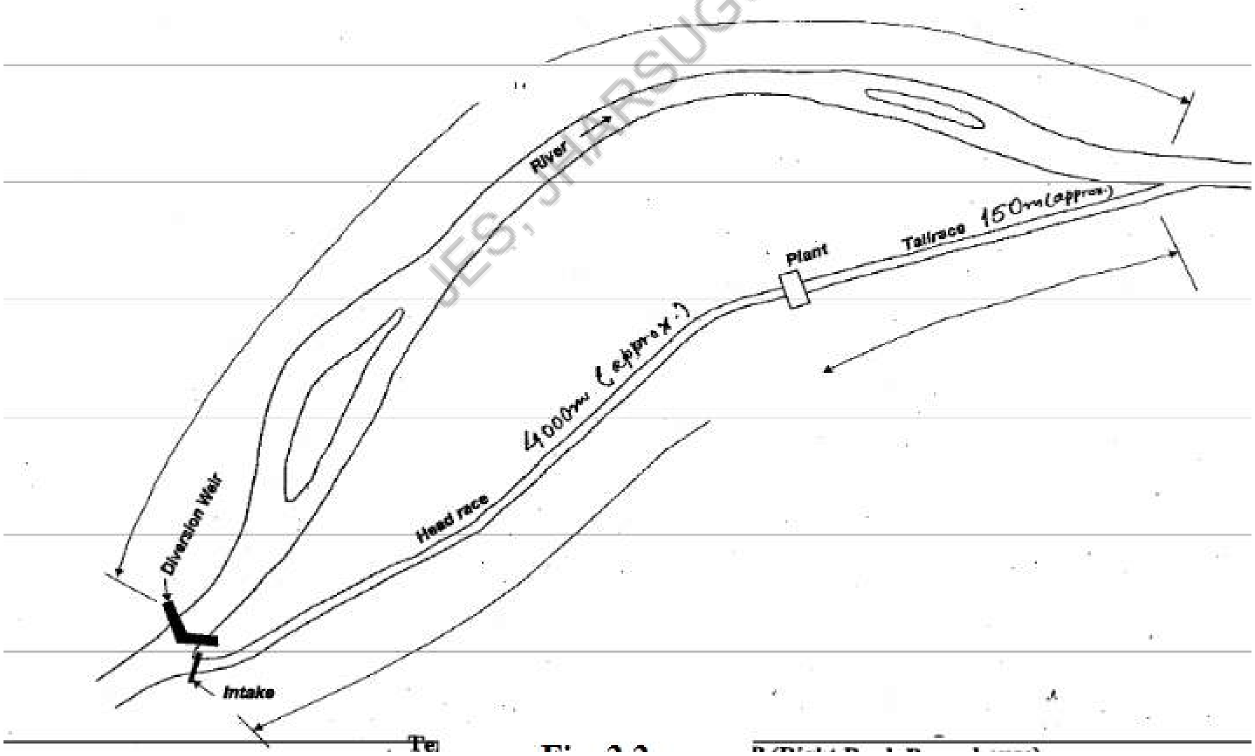
However, when you compare it to the threat of climate change, it is undoubtedly better than any fossil fuel plant. And with over 8,700 new hydro plants being planned in Europe, it is more important than ever to understand the negatives.

CLASSIFICATION OF HYDROPOWER PLANTS
As such there are no hard and fast rules to classify Hydro power plants. Some of the basis are as follows:
•Based on Hydraulic Characteristics
•Based on Head
•Based on Capacity
•Based on Turbine Characteristics
•Based on Load Characteristics
Hydropower Project based on Hydraulic Characteristics:

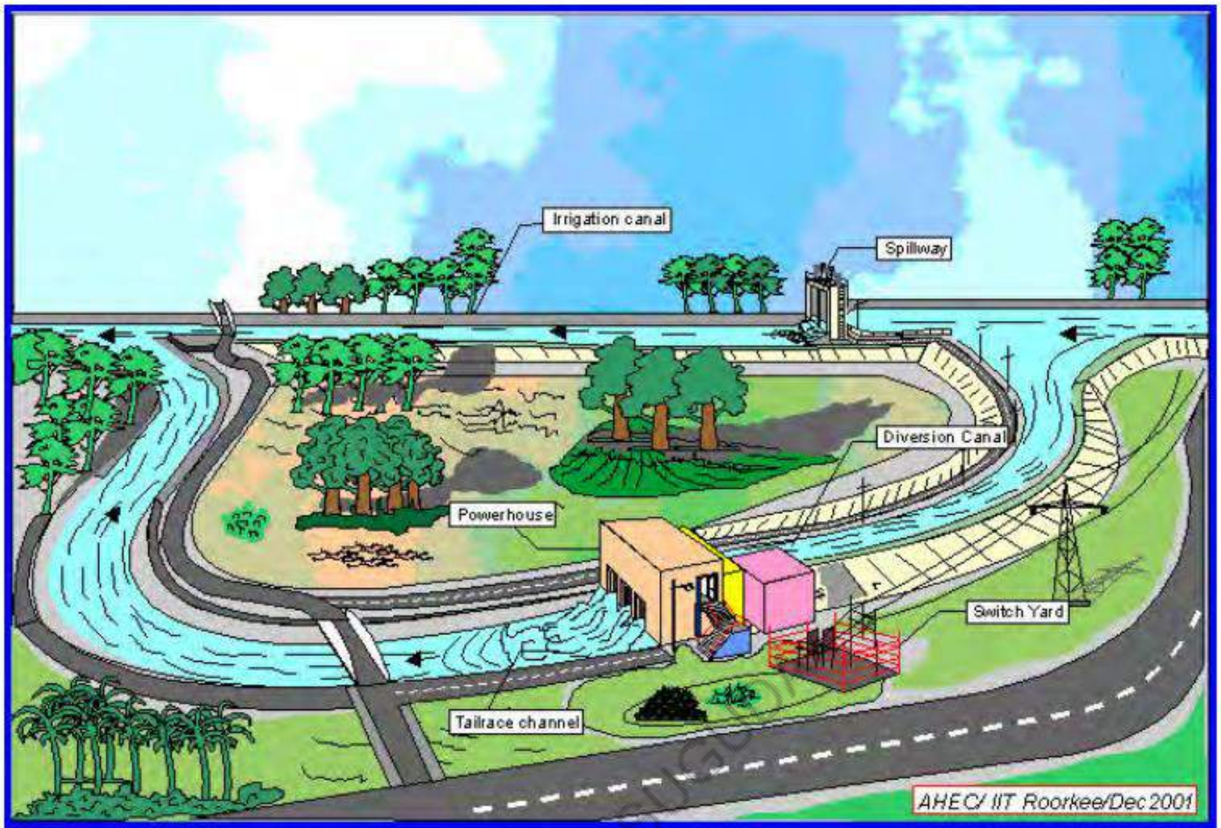
- (i)Run off river plant (Diversion plant)
- (ii) Storage plant (Impoundment plant)
- (iii) Pumped storage plant

Run off River Plant (Diversion Plant)
In some areas of the world, the flow rate and elevation drops of the water are consistent enough that hydro electric plants can be built directly in the river.The water is utilized as it comes in the river. Practically, water is not stored during flood periods as well as during low electricity demand periods, hence water is wasted. Run off river plant may be without pondage or with pondage.
The plants with pondage are provided with a barrage to store the water, to take care of daily variation. During good flow conditions – can supply base load and during low flow conditions - can supply peak load Seasonal changes in river flow and weather conditions affect the plant's output, hence it is in limited use unless interconnected with grid.
flows that occur in the stream at the intake and flows downstream of the powerhouse are virtually identical to pre-development flows.
• Run-of-river facilities use low dams to provide limited storage of water– at most daily pondage
. • In a run-off river SHP scheme, through a diversion structure water is diverted to water conductor system to the powerhouse.
Canal based sites
• A Canal based scheme utilises the drops on existing/proposed irrigation canals. • The energy generated by water flowing through the canal fall (located in the canal) is tapped for power generation. • Powerhouse is located at the main canal or a bye pass canal is constructed where the powerhouse can be located.





Run off river schemes



Typical Arrangement of Canal Fall Small Hydro Power Station

Storage Plant (Impoundment Plant)

A common type of hydro power plant.This plant has storage reservoir provided by constructing a dam across the river.It is generally preferred in mountainous regions. ™The storage of water takes care of fluctuations of water supply during flood and draught period as well as during load fluctuations, hence it can supply electricity more constantly than any other plants ™Suitable for both base load and peak load. ™

Other benefits of this plant are: Flood control Irrigation Drinking water Improved navigation Improved fish breeding etc.

•The dam provides the means to regulate the flow of water, and can add to the height of the source of water thereby effectively increasing the head (H).

•Reservoir created by the dam may store and regulate stream flows to make them more timely for power production, and to serve other purposes for water resource development.

•Powerhouse is located at the toe of the dam and it utilizes the discharge release through sluice primarily meant for irrigation and the head available (water level difference between upstream and downstream of reservoir) for power generation.

A typical scheme is shown in figure

Typical Arrangement of Dam toe Small Hydro Power Station

Pumped Storage Plant:

Water is utilized for generation of power during peak demand, while same water is pumped back in the reservoir during off peak demand period, when excess power is available for this purpose. ™If turbine is reversible, it can be used as a pump to supply water back to reservoir, otherwise separate pump can be used.

Based on operating cycle it can be classified as:

(a) Plant with a daily cycle: water is pumped up from mid night to early morning as well as near lunch time.

(b) Plant with a weekly cycle: water is pumped up during weekend.

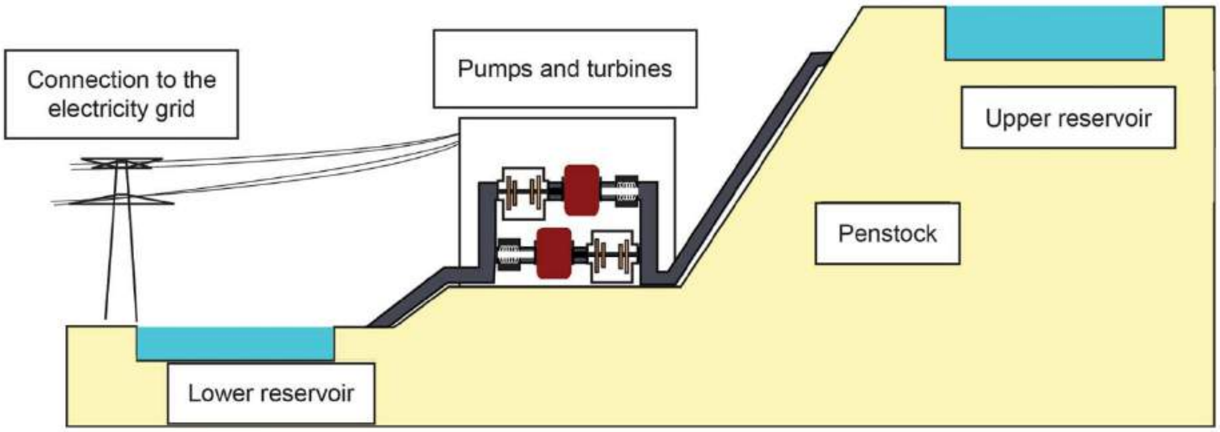
(c) Plant with a seasonal cycle: water is pumped up in the winter continuously for several days to be utilized for a continuous power generation in the high demand summer period.

Pumped-storage power plants are structured around two bodies of water, an upper and a lower reservoir[1] (see the diagram below).

At times of very high electricity consumption on the grid, the water from the upper reservoir, carried downhill by a penstock, drives a turbine and a generator to produce electricity, which is used to meet the increased demand.

When demand is low, electricity is taken from the grid to power a pump that sends water from the lower reservoir back up to the upper reservoir, where it can be discharged again to drive the turbine. In this way, the water in the upper reservoir constitutes a stock of gravitational potential energy , ready to be used when needed.

The stored energy is proportional to the volume of water and the height from which it falls.



Hydropower Projects based on Head

- Low head plant upto 30 m
- (ii) Medium head plant between 30 to 300 m
- (iii) High head plant more than 300 m

Hydro Projects based on Turbine Characteristics (i.e. *Specific speed)
Specific SpeedType of Turbine

- (i)Low specific speed between 10 to 60 Axial flow propeller turbine
- (ii) Medium specific speed between 60 to 300 Francis turbine
- (iii) High specific speed between 300 to 1000 Impulse (pelton) turbine 17

[*Specific speed is the speed of a turbine which is similar to the actual turbine but of such a size that it will develop unit power when working under unit head.]

Hydro Projects Based on Load Characteristics

- Base load plant: Operates continuously and generate constant power throughout the year. e.g. Storage plant, Run off river plant without pondage.
- Peak load plant: Which supply the power during the peak hours only. e.g. Pumped storage plant, Run off river plant with pondage.

SITE SELECTION FOR HYDROELECTRIC POWER PLANT

1.Water Availability:

Main fuel of this plant is water.So, such plant should be located nearer to river,canal etc. where sufficient water is available all the time.

2.**Water Storage:**

Storage of water in a suitable reservoir or dam has to be placed by a careful geological study of the area to get the maximum advantage of that water.Dam should be located across the river to get continuous water supply throughout the year specially in a dry season.The storage capacity of dam can be determined by hydrograph or mass curve or using analytical method.Adequate facilities of erection a dam and storage of water are two important matters for site selection of hydro electric power plant.

3.**Water Head:**

It is an important point for site selection of hydroelectric power plant.Water head is directly related to the cost of generation of electric power.If effective head is increased,water storage has to be reduced as well as capital cost of the plant is reduced.

4.**Distance from the load center:**

Since it is located away from the load center, more transmission line is required to supply the power.To avoid the line loss and economical power supply, distance of such plant should need more attention.

5.**Transportation Facilities:**

Good transportation facilities must be available to any hydro electric power plant, so that necessary equipment should be reached easily.

6.**Availability of land:**

Hydro electric power plant needs enough space.It should be kept in mind that land cost must be cheap. After the location has been chosen the exact position of the various structures are fixed by considering the following factors:

- Details of foundation conditions
- Requirements of head, flow demands for storage capacity
- Arrangement and the type of following:
    - Dam
    - Intake system
    - Conduits
    - Surge tanks
    - Power house
- Cost of dam and project

- ❖ Transport facility and accessibility of site.

Layout of Hydroelectric Power Plants

Hydroelectric power plants convert the hydraulic potential energy from water into electrical energy. Such plants are suitable were water with suitable *head* are available. The layout covered in this article is just a simple one and only cover the important parts of hydroelectric plant.The different parts of a hydroelectric power plant are

(1)Dam

Dams are structures built over rivers to stop the water flow and form a reservoir.The reservoir stores the water flowing down the river. This water is diverted to turbines in power stations. The dams collect water during the rainy season and stores it, thus allowing for a steady flow through the turbines throughout the year. Dams are also used for controlling floods and irrigation. The dams should be water-tight and should be able to withstand the pressure exerted by the water on it. There are different types of dams such as arch dams, gravity dams and buttress dams. The height of water in the dam is called *head race*.

(2)Spillway

A spillway as the name suggests could be called as a way for spilling of water from dams. It is used to provide for the release of flood water from a dam. It is used to prevent over toping of the dams which could result in damage or failure of dams. Spillways could be controlled type or uncontrolled type. The uncontrolled types start releasing water upon water rising above a particular level. But in case of the controlled type, regulation of flow is possible.

(3) Penstock and Tunnel

Penstocks are pipes which carry water from the reservoir to the turbines inside power station. They are usually made of steel and are equipped with gate systems. Water under high pressure flows through the penstock. A tunnel serves the same purpose as a penstock. It is used when an obstruction is present between the dam and power station such as a mountain.

- Pressure Shaft/penstock is enclosed pipe/channel used to deliver/feed water to hydraulic turbines in respect of hydro power plant.
- Pressure tunnels must be kept far below the lowest possible hydraulic gradient to avoid, the creation of vacuum and the consequent risks of unstable flow, cavitation and collapse of lining.

Total friction losses in the tunnel must not be great enough to impair the output and the regulation of machines.

(4) Power house

Power house is a station for generation of electricity. It houses equipment and personnel working in a power generating station.

Essential components of the power house are:

a) Machine hall.

b) Unloading and erection bay.

c) Annexes or Extensions

d) or ducts for cables, bus-bars and pipes

e) Control room

f) Passages Workshop

g) Storage space

h) Office and administrative accommodation.

HYDRO TURBINES

Classified into two categories:

Impulse Turbine

a) Uses the velocity of water to move the runner & discharges to atmospheric pressure.

b) The water stream hits each bucket on the runner.

c) There is no suction on the down side of the turbine.

d) Water flows out the bottom of the turbine housing after hitting the runner.

e) Generally suitable for high head, low flow applications ex- pelton wheel

Reaction Turbine

a) Develops power from the combined action of pressure and moving water

b) Runner is placed directly in the water stream flowing over the blades rather than striking each individually

c) Used for sites with lower head and higher flows

ex- francis turbine, Kaplan turbine, propeller turbine etc

List of Major Hydro Power Stations in India

Plant Name	No of Units x Size	Total Capacity	Group Company	State
Bhakra Dam	5*108	540	BBMB	Punjab
Bhakra Dam	5*157	785	BBMB	Punjab
GANGUWAL	1*29.25+2*24.2	77.65	BBMB	Himachal Pradesh
KOTLA	1*29.25+2*24.2	77.65	BBMB	Himachal Pradesh
Dehar (Pandoh)	6*165	990	BBMB	Himachal Pradesh
LOWER JHELUM	3*35	105	J&KSPDC	Jammu & Kashmir
UPPER SINDH – II	3*35	105	J&KSPDC	Jammu & Kashmir
BAGLIHAR	3*150	450	J&KSPDC	Jammu & Kashmir
SHANAN	4*15+1*50	110	PSPCL	Punjab
MUKERIAN ST-I PH-I	3*15	45	PSPCL	Punjab
MUKERIAN ST-I PH-II	3*15	45	PSPCL	Punjab
MUKERIAN ST-I PH-III	3*19.5	58.5	PSPCL	Punjab
MUKERIAN ST-I PH-IV	3*19.5	58.5	PSPCL	Punjab
A.P.SAHIB ST.I	2*33.5	67	PSPCL	Punjab
A.P.SAHIB ST.II	2*33.5	67	PSPCL	Punjab
RANJIT SAGAR DAM	4*150	600	PSPCL	Punjab
R.P.SAGAR	4*43	172	RRJVUNL	RAJASTHAN
J.SAGAR	3*33	99	RRJVUNL	RAJASTHAN
MAHIBAJAJ – I	2*25	50	RRJVUNL	RAJASTHAN
MAHIBAJAJ – II	2*45	90	RRJVUNL	RAJASTHAN
RIHAND	6*50	300	UPJVNL	UTTAR PRADESH
OBRA	3*33	99	UPJVNL	UTTAR PRADESH
MATATILLA	3*10.2	30.6	UPJVNL	UTTAR PRADESH
KHARA	3*24	72	UPJVNL	UTTAR PRADESH
DHAKRANI	3*11.25	33.75	UJVNL	UTTARAKHAND
DHALIPUR	3*17	51	UJVNL	UTTARAKHAND

KULHAL	3*10	30	UJVNL	UTTARAKHAND
CHIBRO	4*60	240	UJVNL	UTTARAKHAND
KHODRI	4*30	120	UJVNL	UTTARAKHAND
RAMGANGA	3*66	198	UJVNL	UTTARAKHAND
CHILLA	4*36	144	UJVNL	UTTARAKHAND
MANERIBHALI (THILOT) ST.-I	3*30	90	UJVNL	UTTARAKHAND
MANERIBHALI STAGE-II	4*76	304	UJVNL	UTTARAKHAND
KHATIMA	3*13.8	41.4	UJVNL	UTTARAKHAND
VISHNUPRAYAG	4*100	400	JAIPRAKASH POWER VENTURE LTD. (PVT.)	UTTARAKHAND
UKAI	4*75	300	GSECL	GUJARAT
KADANA (PSS)	4*60	240	GSECL	GUJARAT
SARDAR SAROVAR-CHPH	5*50	250	SSNNL	GUJARAT
SARDAR SAROVAR-RBPH	6*200	1200	SSNNL	GUJARAT
INDIRA SAGAR	8*125	1000	NHDC	MADHYA PRADESH
OMKARESHWAR	8*65	520	NHDC	MADHYA PRADESH
GANDHI SAGAR	5*23	115	MPGPCL	MADHYA PRADESH
RANI AWANTI BAI SAGAR	2*45	90	MPGPCL	MADHYA PRADESH
PENCH	2*80	160	MPGPCL	MADHYA PRADESH
BAN SAGAR TONS – I	3*105	315	MPGPCL	MADHYA PRADESH
BANSAGAR TONS-II	2*15	30	MPGPCL	MADHYA PRADESH
BANSAGAR TONS-III	3*20	60	MPGPCL	MADHYA PRADESH
RAJGHAT	3*15	45	MPGPCL	MADHYA PRADESH
MADHIKHERA	3*20	60	MPGPCL	MADHYA PRADESH
HANSDEO BANGO	3*40	120	CSPGC	CHHATISGARH
KOYNA I&II	4*70+4*80	600	MAHANGENCO	MAHARASHTRA
KOYNA III	4*80	320	MAHANGENCO	MAHARASHTRA
KOYNA IV	4*250	1000	MAHANGENCO	MAHARASHTRA
KOYNA DPH	2*18	36	MAHANGENCO	MAHARASHTRA
VAITARNA	1*60	60	MAHANGENCO	MAHARASHTRA
BIRA TAIL RACE	2*40	80	MAHANGENCO	MAHARASHTRA
TILLARI	1*60	60	MAHANGENCO	MAHARASHTRA
GHATGHAR PSS	2*125	250	MAHANGENCO	MAHARASHTRA
BHIRA	6*25	150	TATA POWER COMPANY (PVT.)	MAHARASHTRA

BHIVPURI	3*24+2*1.5	75	TATA POWER COMPANY (PVT.)	MAHARASHTRA
KHOPOLI	3*24	72	TATA POWER COMPANY (PVT.)	MAHARASHTRA
BHIRA PSS	1*150	150	TATA POWER COMPANY (PVT.)	MAHARASHTRA
BANDHARDHARA – II	1*34	34	DODSON-LINDBLOM HYDRO POWER PVT. LTD. (DLHP)	MAHARASHTRA
MACHKUND	3*17+3*21.25	114.75	APGENCO	ANDHRA PRADESH
UPPER SILERU ST-I	2*60	120	APGENCO	ANDHRA PRADESH
UPPER SILERU ST-II	2*60	120	APGENCO	ANDHRA PRADESH
LOWER SILERU	4*115	460	APGENCO	ANDHRA PRADESH
T.B.DAM	4*9	36	APGENCO	ANDHRA PRADESH
HAMPI	4*9	36	APGENCO	ANDHRA PRADESH
N.J.SAGAR	1*110+7*100.8	815.6	APGENCO	ANDHRA PRADESH
SRISAILAM	7*110	770	APGENCO	ANDHRA PRADESH
N.J.SAGAR RBC	2*30	60	APGENCO	ANDHRA PRADESH
N.J.SAGAR RBC EXT.	1*30	30	APGENCO	ANDHRA PRADESH
N.J.SAGAR LBC	2*30	60	APGENCO	ANDHRA PRADESH
POCHAMPAD	3*9	27	APGENCO	ANDHRA PRADESH
SRISAILAM LBPH	6*150	900	APGENCO	ANDHRA PRADESH
PRIYDARSHNI JURALA	6*39	234	APGENCO	ANDHRA PRADESH
SHARAVATHY	10*103.5	1035	KPCL	KARNATAKA
LINGNAMAKKI	2*27.5	55	KPCL	KARNATAKA
BADHRA	1*2+2*12+1*7.20+1*	39.2	KPCL	KARNATAKA
KALINADI	3*135+3*150	855	KPCL	KARNATAKA
SUPA DPH	2*50	100	KPCL	KARNATAKA
VARAHI	4*115	460	KPCL	KARNATAKA
GHATPRABHA	2*16	32	KPCL	KARNATAKA
KADRA	3*50	150	KPCL	KARNATAKA
KODASALI	3*40	120	KPCL	KARNATAKA
SHARAVATHY TAIL RACE	4*60	240	KPCL	KARNATAKA
ALMATTI DAM	1*15+5*55	290	KPCL	KARNATAKA
JOG	4*13.2+4*21.6	139.2	KPCL	KARNATAKA
SIVASAMUDRAM	6*3+4*6	42	KPCL	KARNATAKA
MUNIRABAD	2*9+1*10	28	KPCL	KARNATAKA
IDUKKI	6*130	780	KSEB	KERALA
SABARIGIRI	6*50	300	KSEB	KERALA
KUTTIYADI & K. EXTN.	3*25+1*50	125	KSEB	KERALA

KUTTIYADI ADDN. EXTN.	2*50	100	KSEB	KERALA
SHOLAYAR	3*18	54	KSEB	KERALA
SENGULAM	4*12	48	KSEB	KERALA
NARIAMANGLAM	3*15+1*25	70	KSEB	KERALA
PALLIVASAL	3*5+3*7.5	37.5	KSEB	KERALA
PORINGALKUTTU	4*8	32	KSEB	KERALA
PANNIAR	2*15	30	KSEB	KERALA
IDAMALAYAR	2*37.5	75	KSEB	KERALA
LOWER PERIYAR	3*60	180	KSEB	KERALA
KAKKAD	2*25	50	KSEB	KERALA
KUNDAH- I	3*20	60	TNEB	Tamilnadu
KUNDAH- II	5*35	175	TNEB	Tamilnadu
KUNDAH- III	3*60	180	TNEB	Tamilnadu
KUNDAH- IV	2*50	100	TNEB	Tamilnadu
KUNDAH-V	2*20	40	TNEB	Tamilnadu
PARSON'S VALLEY (K.-VI)	1*30	30	TNEB	Tamilnadu
METTUR DAM	4*12.5	50	TNEB	Tamilnadu
METTUR TUNNEL	4*50	200	TNEB	Tamilnadu
PERIYAR	4*35	140	TNEB	Tamilnadu
KODAYAR- I	1*60	60	TNEB	Tamilnadu
KODAYAR- II	1*40	40	TNEB	Tamilnadu
SHOLAYAR	2*35+1*25	95	TNEB	Tamilnadu
PYKARA	3*7+1*11+2*13.6	59.2	TNEB	Tamilnadu
ALIYAR	1*60	60	TNEB	Tamilnadu
SARKARPATHY	1*30	30	TNEB	Tamilnadu
PAPANASAM	4*8	32	TNEB	Tamilnadu
MOYAR	3*12	36	TNEB	Tamilnadu
SURULIYAR	1*35	35	TNEB	Tamilnadu
L.MET.PH-1	2*15	30	TNEB	Tamilnadu
L.MET.PH-2	2*15	30	TNEB	Tamilnadu
L.MET.PH-3	2*15	30	TNEB	Tamilnadu
L.MET.PH-4	2*15	30	TNEB	Tamilnadu
KADAMPARAI	4*100	400	TNEB	Tamilnadu
PYKARA ULTIMATE	3*50	150	TNEB	Tamilnadu
BHAWANI BARRAGE – I	2*15	30	TNEB	Tamilnadu
BHAWANI BARRAGE – III	1*15	15	TNEB	Tamilnadu
SUBERNREKHA – I	1*65	65	JSEB	JHARKHAND
SUBERNREKHA – II	1*65	65	JSEB	JHARKHAND

MAITHON	2*20+1*23.2	63.2	D.V.C.	JHARKHAND
PANCHET & EXTN.	2*40	80	D.V.C.	JHARKHAND
HIRAKUD – I (BURLA)	2*49.5+2*32+3*37.5	275.5	OHPC	ORISSA
HIRAKUD – II (CHIPLIMA)	3*24	72	OHPC	ORISSA
BALIMELA	6*60+2*75	510	OHPC	ORISSA
RENGALI	5*50	250	OHPC	ORISSA
UPPER KOLAB	4*80	320	OHPC	ORISSA
UPPER INDRAVATI	4*150	600	OHPC	ORISSA
JALDHAKA – I	3*9	27	WBSEDCL	WEST BENGAL
RAMMAM-II	4*12.5	50	WBSEDCL	WEST BENGAL
PURULIA PSS	4*225	900	WBSEDCL	WEST BENGAL
RANGIT-III	3*20	60	NHPC (ER)	SIKKIM
TEESTA	3*170	510	NHPC (ER)	SIKKIM
KARBI LANGPI	2*50	100	APGCL	ASSAM
KYRDEMKULAI	2*30	60	MeSEB	MEGHALAYA
UMIAM ST-I	4*9	36	MeSEB	MEGHALAYA
UMIAM ST- IV	2*30	60	MeSEB	MEGHALAYA
MYNTDU ST.- I	2*42	84	MeSEB	MEGHALAYA
KHANDONG	3*25	75	NEEPCO	MEGHALAYA
KOPILI	4*50	200	NEEPCO	MEGHALAYA
DOYANG	3*25	75	NEEPCO	MEGHALAYA
RANGANADI	3*135	405	NEEPCO	MEGHALAYA
LOKTAK	3*35	105	NHPC (NER)	MANIPUR

GAS TURBINE:

Site selection of gas turbine power plant

While selecting the site for a gas turbine power plant, following points should be given due consideration:

1. The plant should be located near the load centre to avoid transmission costs and losses.
2. The site should be away from business centre due to noisy operations.
3. Cheap and good quality fuel should be easily available.
4. Availability of labour.
5. Availability of means of transportation.