LECTURE NOTES OF

POWERSTATION ENGINEERING

6TH SEMESTER – MECHANICAL ENGINEERING

PREPARED BY :

Er. MANOROMA SARABU

Sr. LECTURER

GOVERNMENT POLYTECHNIC, KORAPUT

MECHANICAL POWER PLANT ENGG. 6TH.

CHAPTER.1

Sources of energy

Energy sources are categorized as **renewable** or **non-renewable**.

- **Renewable energy** is collected from renewable resources. A source of energy is considered renewable if it comes from natural sources or processes that are constantly replenished. Examples are solar (from the sun), wind, water, geothermal (from the earth) and biomass (from organic materials).

- **Non-renewable energy** sources don't replenish, and are formed when prehistoric plants and animals died and were gradually buried by layers of soil rock. The kind of fuel that was created varied depending on the conditions like what kind of organic material (from plants or animals), how long it was buried, at what temperature and under what pressure. Types of non-renewable energy are natural gas, coal and oil.

Types of energy

- **Chemical energy** – stored within bonds between molecules. Sources include natural gas, gasoline, coal and batteries. Even the food we eat is considered chemical energy.
- **Electrical energy** – comes from tiny charged particles called electrons. A lightning bolt is one form of electrical energy. The electricity in our homes is made by humans.
- **Gravitational energy** – associated with a gravitational field, like the one that surrounds the Earth. If you've ever fallen down, you've experienced the power of gravitational energy. Gravitational energy is the reason why riding your bike downhill is faster than riding your bike uphill.
- **Kinetic energy** – anything that moves is using this kind of energy. Examples include running, cycling, climbing – even swiping your finger across your smart phone! Wind turbines capture the kinetic energy in wind and transform it into mechanical energy.
- **Mechanical energy** – stored in objects by tension. When the tension is released, motion occurs. A compressed spring contains mechanical energy as does a stretched rubber band.
- **Nuclear energy** – stored inside tiny atoms that are invisible, but make up the elements of the entire universe. Nuclear energy is released when atoms join together (fusion) or split (fission). The fusion reaction in the sun provides warmth and light, while the fission reaction at a nuclear power plant creates enough energy to power large cities.
- **Solar (radiant) energy** – energy that comes from the movement of light.
- **Sound energy** – produced when an object is made to vibrate producing a sound. Your voice and musical instruments use sound energy.

Thermal (heat) energy – created from moving molecules. The energy that comes from a fire is thermal energy.

CENTRAL AND INDUSTRIAL POWER STATION

A captive power plant is a facility dedicated to provide energy for a single user. The user can be a industrial facility or large offices. For example, a steel plant needs power to operate its equipment's; the power to the plant is produced by the captive power plant dedicated to it. The CPP's may operate in grid parallel mode i.e it can send the surplus power to grid.

Centralized power is just the **idea** of building a big **power** plant that supplies a large number of people rather than distributed **generation** where (say) everybody has their own solar **power .....**Things like hydro and wind **power** also tend to be done large, but are located where water and wind are rather than centrally.

What is Power Plant?

A **power plant** or a **power generating station**, is basically an industrial location that is utilized for the generation and distribution of electric power in mass scale, usually in the order of several 1000 Watts. These are generally located at the sub-urban regions or several kilometres away from the cities or the load centres, because of its requisites like huge land and water demand, along with several operating constraints like the waste disposal etc.
For this reason, a power generating station has to not only take care of efficient generation but also the fact that the power is transmitted efficiently over the entire distance and that's why, the transformer switch yard to regulate transmission voltage also becomes an integral part of the **power plant**.
At the center of it, however, nearly all power generating stations has an AC generator or an alternator, which is basically a rotating machine that is equipped to convert energy from the mechanical domain (rotating turbine) into electrical domain by creating relative motion between a magnetic field and the conductors.

The energy source harnessed to turn the generator shaft varies widely, and is chiefly dependent on the type of fuel used.

Types of Power Plant

A **power plant** can be of several types depending mainly on the type of fuel used. Since for the purpose of bulk power generation, only thermal, nuclear and hydro power comes handy, therefore a power generating station can be broadly classified in the 3 above mentioned types. Let us have a look in these **types of power stations** in details.

Thermal Power plant

A thermal power station or a coal fired thermal power plant is by far, the most conventional method of generating electric power with reasonably high efficiency. It uses coal as the primary fuel to boil the water available to superheated steam for driving the steam turbine.

The steam turbine is then mechanically coupled to an alternator rotor, the rotation of which results in the generation of electric power. Generally in India, bituminous coal or brown coal are used as fuel of boiler which has volatile content ranging from 8 to 33% and ash content 5 to 16 %. To enhance the thermal efficiency of the plant, the coal is used in the boiler in its pulverized form.

In coal fired thermal power plant, steam is obtained in very high pressure inside the steam boiler by burning the pulverized coal. This steam is then super heated in the super heater to extreme high temperature. This super heated steam is then allowed to enter into the turbine, as the turbine blades are rotated by the pressure of the steam.

The turbine is mechanically coupled with alternator in a way that its rotor will rotate with the rotation of turbine blades. After entering into the turbine, the steam pressure suddenly falls leading to corresponding increase in the steam volume. After having imparted energy into the turbine rotors, the steam is made to pass out of the turbine blades into the steam condenser of turbine. In the condenser, cold water at ambient temperature is circulated with the help of pump which leads to the condensation of the low pressure wet steam.

Then this condensed water is further supplied to low pressure water heater where the low pressure steam increases the temperature of this feed water, it is again heated in high pressure. This outlines the basic working methodology of a thermal power plant.

Advantages of Thermal Power Plants

- Fuel used i.e. coal is quite cheaper.
- Initial cost is less as compared to other generating stations.
- It requires less space as compared to hydro-electric power stations.

Disadvantages of Thermal Power Plants

- It pollutes atmosphere due to production of smoke and fumes.
- Running cost of the power plant is more than hydro electric plant.

Nuclear Power plant

Nuclear power plants are similar to the thermal stations in more ways than one. However, the exception here is that, radioactive elements like uranium and thorium are used as the primary fuel in place of coal. Also in a Nuclear station the furnace and the boiler are replaced by the nuclear reactor and the heat exchanger tubes. For the process of nuclear power generation, the radioactive fuels are made to undergo fission reaction within the nuclear reactors. The fission reaction, propagates like a controlled chain reaction and is accompanied by unprecedented amount of energy produced, which is manifested in the form of heat.

This heat is then transferred to the water present in the heat exchanger tubes. As a result, super heated steam at very high temperature is produced. Once the process of steam formation is accomplished, the remaining process is exactly similar to a thermal power plant, as this steam will further drive the turbine blades to generate electricity.

Hydro-Electric Power Station

In Hydro-electric plants the energy of the falling water is utilized to drive the turbine which in turn runs the generator to produce electricity. Rain falling upon the earth's surface has potential energy relative to the oceans towards which it flows. This energy is converted to shaft work where the water falls through an appreciable vertical distance. The hydraulic power is therefore a naturally available renewable energy given by the eqn:

$P = g\varrho QH$

Where, g = acceleration due to gravity = 9.81 m/sec^2

ϱ = density of water = 1000 kg/m^3

H = height of fall of water.

This power is utilized for rotating the alternator shaft, to convert it to equivalent electrical energy.

An important point to be noted is that, the hydro-electric plants are of much lower capacity compared to their thermal or nuclear counterpart. For this reason hydro plants are generally used in scheduling with thermal stations, to serve the load during peak hours. They in a way assist the thermal or the nuclear plant to deliver power efficiently during periods of peak hours.

Advantages of Hydro Electric Power Station

- It requires no fuel; water is used for generation of electrical energy.
- It is neat and clean energy generation.

- Construction is simple, less maintenance is required.
- It helps in irrigation and flood control also.

Disadvantages Hydro Electric Power Station

- It involves high capital cost due to dam construction.
- Availability of water depends upon weather conditions.
- It requires high transmission cost as the plant is located in hilly areas.

Types of Power Generation

As mentioned above, depending on the type of fuel used, the **power generating stations** as well as the types of power generation are classified. Therefore the 3 major classifications for power production in reasonably large scale are:

1. Thermal power generation
2. Nuclear power generation
3. Hydro-electric power generation

Apart from these major types of power generations, we can resort to small scale generation techniques as well, to serve the discrete demands. These are often referred to as the alternative methods or non conventional energy of power generation and can be classified as :-

1. Solar power generation. (making use of the available solar energy)
2. Geo-thermal power generation. (Energy available in the Earth's crust)
3. Tidal power generation.

Wind power generation (energy available from the wind turbines)

These alternative sources of generation has been given due importance in the last few decades owing to the depleting amount of the natural fuels available to us. In the centuries to come, a stage might be reached when several countries across the globe would run out of their entire reserve for fossil fuels.

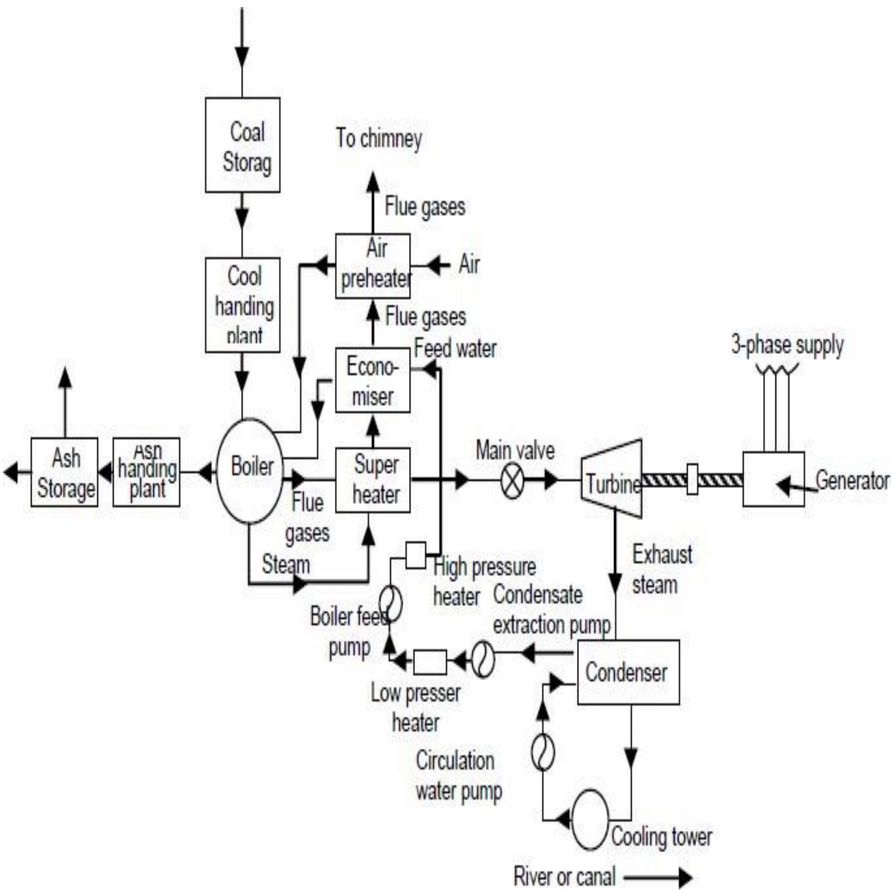
The only way forward would then lie in the mercy of these alternative sources of energy which might play an instrumental role in shaping the energy supplies of the future. For this reason these might rightfully be referred as the energy of the future.

A power plant may be defined as a machine or assembly of equipment that generates and delivers a flow ofmechanical or electrical energy. The main equipment for the generation of electric power is generator. When coupling it to
a prime mover runs the generator, the electricity is generated. The type of prime move determines the type of powerplants. The major power plants,

1. Steam power plant
2. Diesel power plant
3. Gas turbine power plant
4. Nuclear power plant
5. Hydro electric power plant

The Steam Power Plant, Diesel Power Plant, Gas Turbine Power Plant and Nuclear Power Plants are called **THERMAL POWER PLANT,** because these convert heat into electric energy.

LAYOUT OF STEAM POWER PLANT:-



__A steam power plant must have following equipments__:

1. A furnace to burn the fuel.
2. Steam generator or boiler containing water. Heat generated in the furnace is utilized to convert water in steam.
3. Main power unit such as an engine or turbine to use the heat energy **of** steam and perform work .
4. Piping system to convey steam and water.

The flow sheet of a thermal power plant consists of the following fourmaincircuits:

(i) Feed water and steam flow circuit

(ii) Fig.

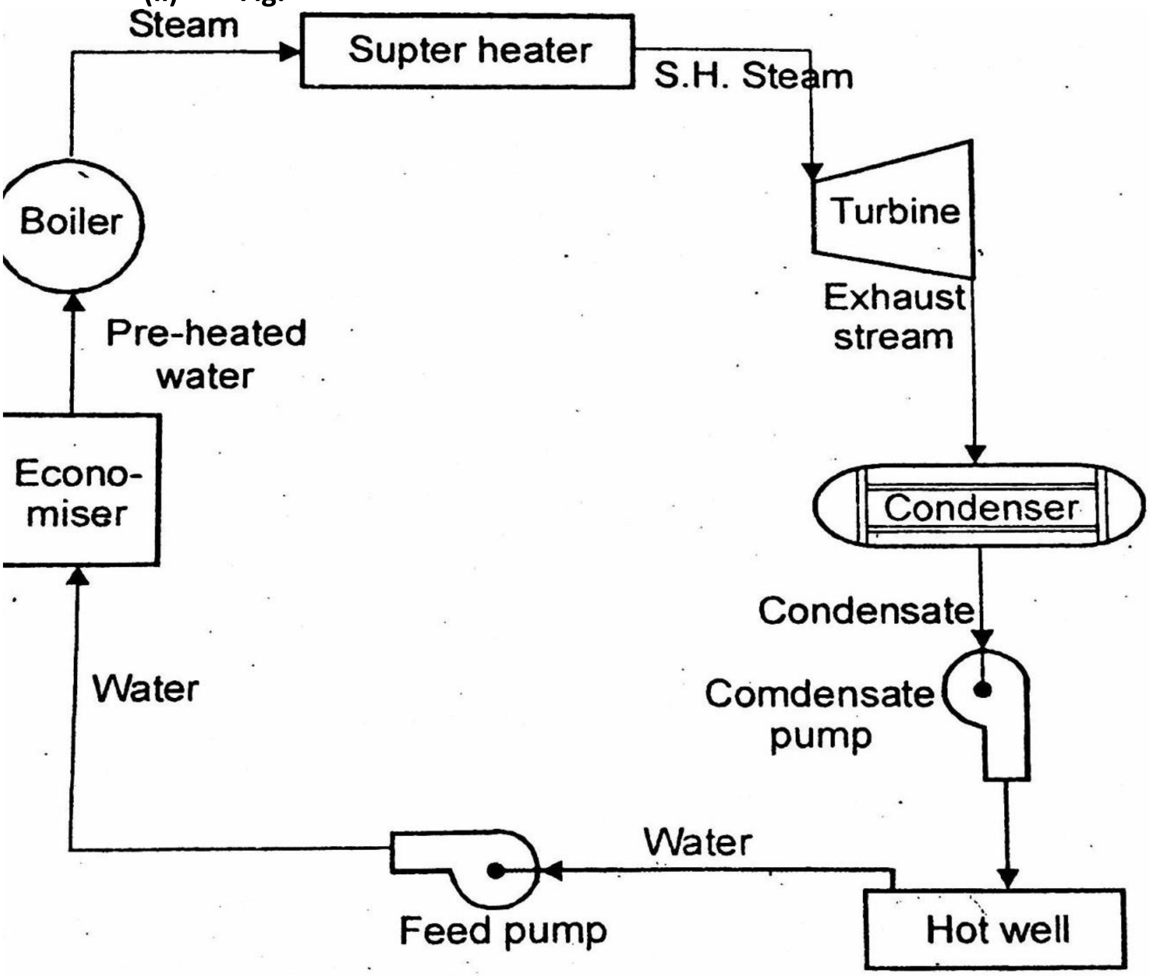


Figure : Water and Steam circuit.

(iii) Coal and ash circuit

FIGURE:-

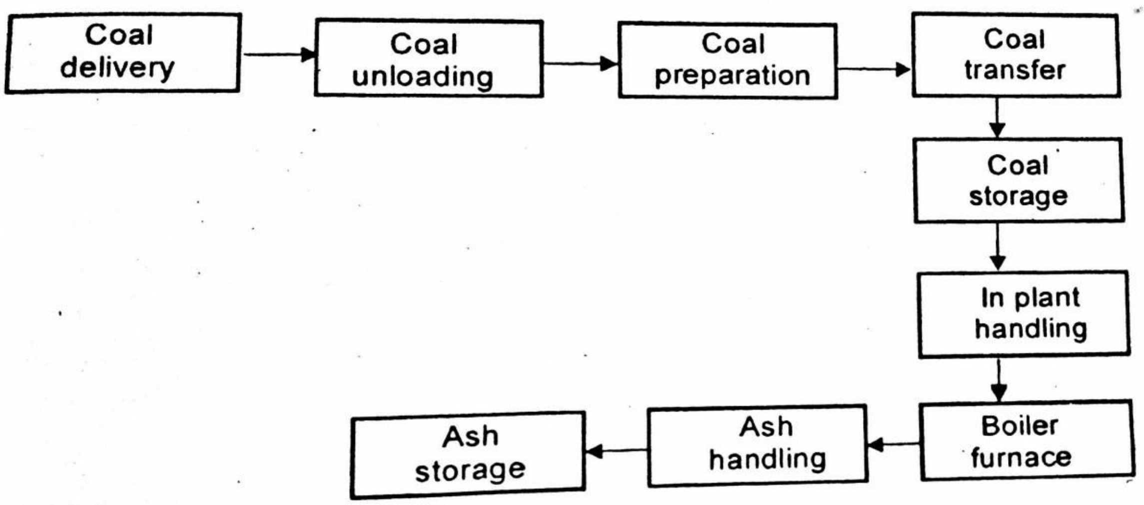


Figure : Fuel (coal) and ash circuit.

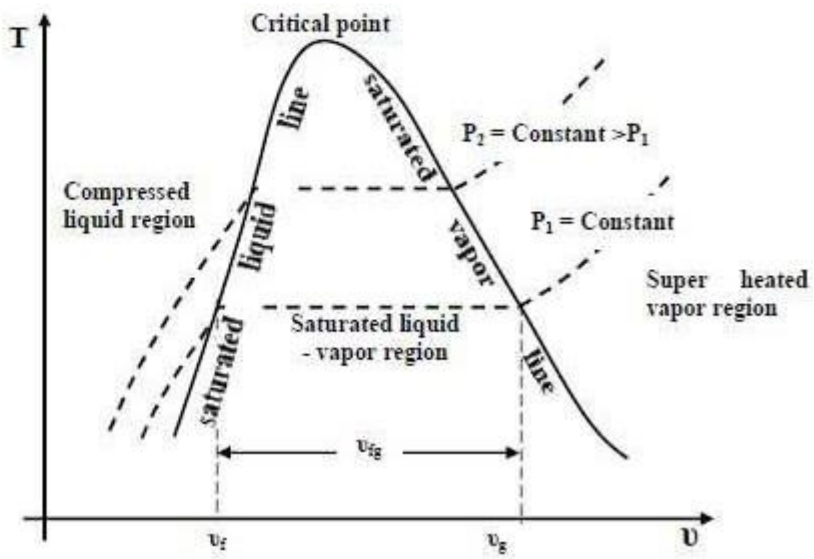
(*iii)* Air and gas circuit

The different types of systems and components used in steam power plant are as follows:

(i) High pressure boiler
(ii) Prime mover
(iii) Condensers and cooling towers
(iv) Coal handling system
(v)Ash and dust handling system
(vi) Draught system
(vii) Feed water purification plant
(viii) Pumping system
(ix) Air preheater, economizer, super heater, feed heaters.

Important Points:

• **Saturation temperature:** is the temperature of a pure substance start boiling at certain pressure, this pressure is
Called saturation pressure.
• **Saturated liquid**: if a pure substance exists as liquid at saturation temperature and pressure, it is called saturated liquid.
• **Wet mixture**: is the mixture of liquid andits vapour.
• **Saturated vapour**: if a pure substance exists as vapour at saturated temperature and pressure, it is called saturated vapour.
• **Moisture content**: is the ratio of liquid mass to the total mass (mass of liquid and mass of vapour). y=ml/(ml+mv)
• **Dryness fracture (x): is a ratio of vapour mass to the total mass. x=mv/(ml+mv)**
y+x=1



• **Enthalpy of vaporization (hfg):** or **latent heat of vaporization**:-It represent the amount of energy needed to vaporize a unit mass of saturated liquid at a given temperature or pressure. It decreases as the temperature or pressure increases, and it is becomes Zero at the critical point.

• **Super heated vapour:** When the temperature of the vapour is higher than the saturated temperature of this vapour is called super heated vapour.

• **Degree of super heated:** is the difference between the saturated temperature and superheated temperature.

Degree = Tsup. - Tsat.

• **Enthalpy of water (hf):** is the enthalpy of heat absorbed by unit mass of water at constant pressure until it reaches to the temperature of vapour forming from (0 oC).

hf = c (T - 0)

• T: temp. of vapour forming.

• c: specific heat of water (4.2 kJ/kg.k)

• **Enthalpy of dry steam (hg):** is the quantity of head which needed to change unit mass of water at (0 oC) to dry steam.

Hg = hf + (hfg)

• **Enthalpy of wet steam (hx):**

Hx = (1 - x) hf + x hg

• This relation can also be expressed as

Hx = hf + x hfg (WHERE: x is a dryness of vapour mixture)

Basic Consideration in the Analysis of Power Cycles

1. Actual Cycle

• The cycles encountered in actual devices are difficult to analyse because of the presence of complicating effects, such as friction and the absence of sufficient time for establishment of the equilibrium conditions during the cycle.

2. Ideal Cycle

• When the actual cycle is stripped of all the internal Irreversibility's and complexities, we end up with a Cycle that resembles the actual cycle closely but is made up totally of internally reversible processes.Such a cycle is called ***an Ideal cycle***.

Steam Cycle

• Steam cycle thermal power plant are designed for the purpose of converting primary energy resources to work and their performance is expressed as thermal efficiency.

The Idealization and Simplification of steam cycle:

a) The cycle does not involve any friction.
b) All expansion and compression process take place in aquasi equilibrium manner.
c) The pipe connecting the various component of asystem are well insulated and heat transfer andpressure drop through them are negligible.

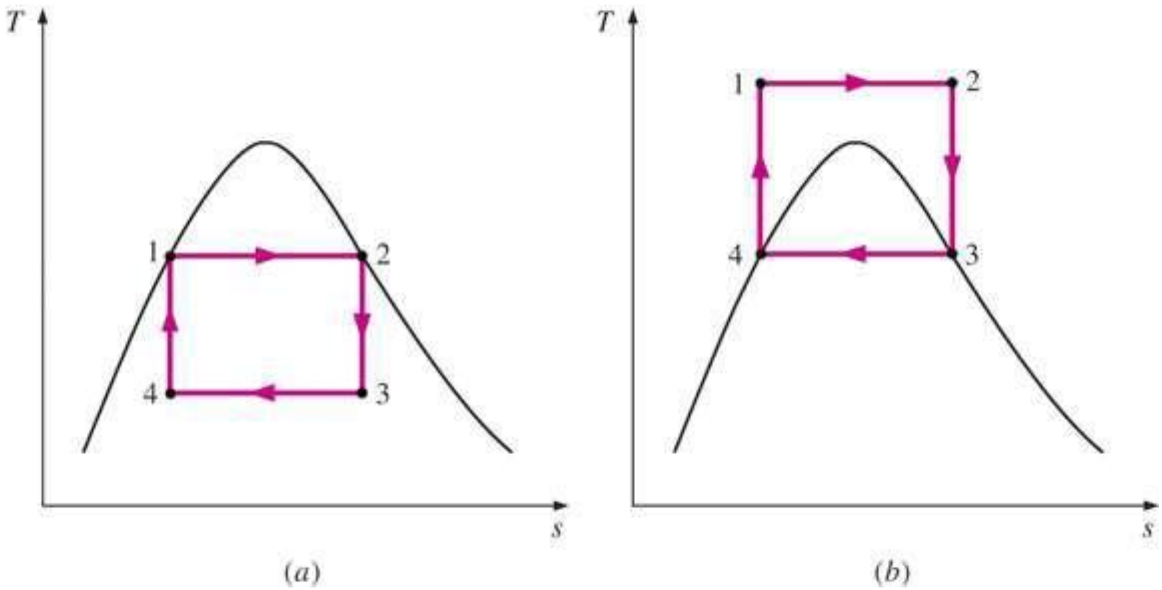
THE CARNOT VAPOR CYCLE

T-s diagram of Carnot vapour cycles.

The Carnot cycle is the most efficient cycle operating between two specified temperature limits but it is not a suitable model for power cycles. Because:
Process 1-2 Limiting the heat transfer processes to two-phase systems severely limits the Maximum temperature that can be used in the cycle (373.95°C and 22.06 Mpa for water)
Process 2-3 The turbine cannot handle steam with a high moisture content because of the Impingement of liquid droplets on the turbine blades causing erosion and wear.
Process 4-1 It is not practical to design a compressor that handles two phases.

The cycle in (b) is not suitable since it requires isentropic compression to extremely high-pressures and isothermal heat transfer at variable pressures.

1-2 isothermal heat addition in

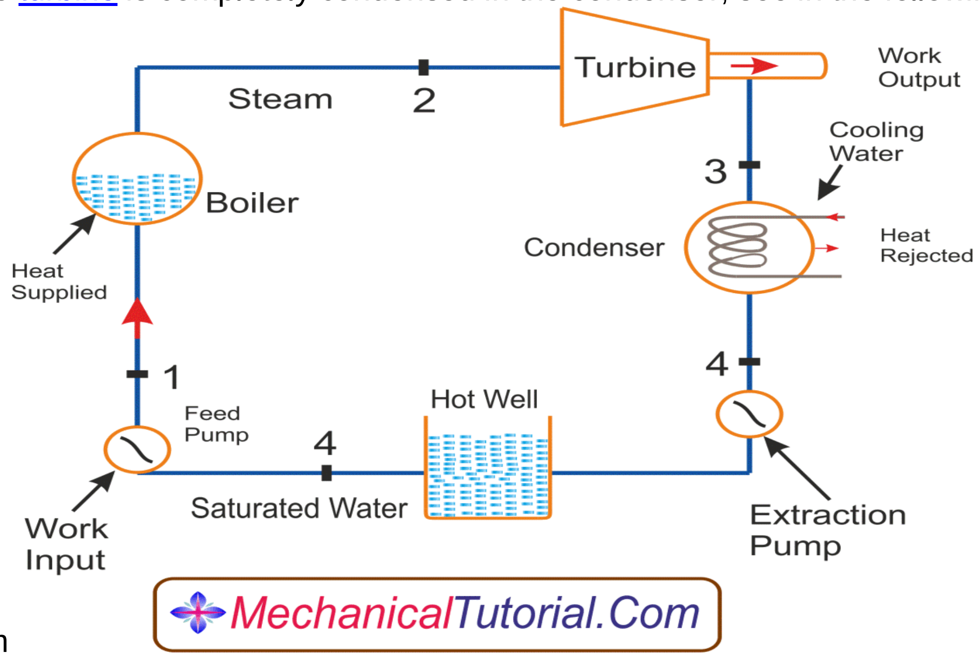


a boiler (TH)
2-3 isentropic expansion in turbine
3-4 isothermal heat rejection ina condenser (TL)
4-1 isentropic compression in compressor
Thermal efficiency of Carnot cycle

=WORK DONE/HEAT SUPPLIED

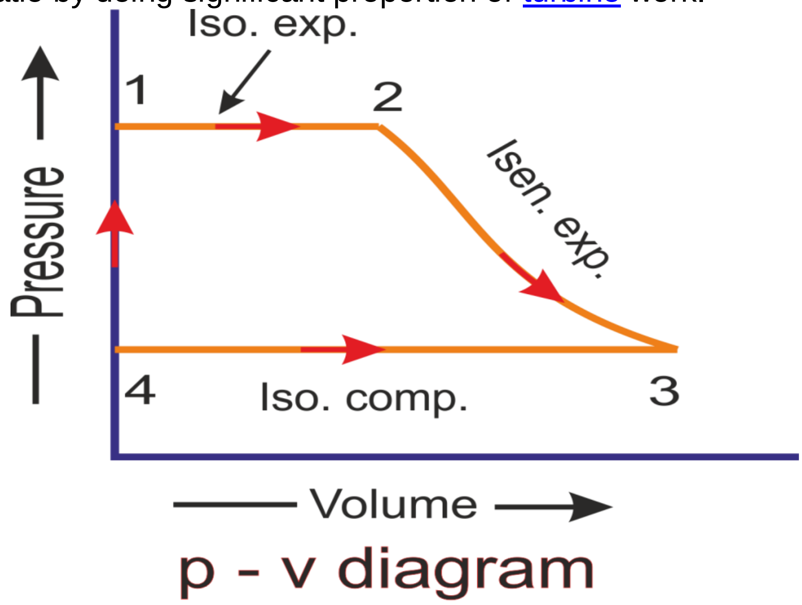
Rankine cycle

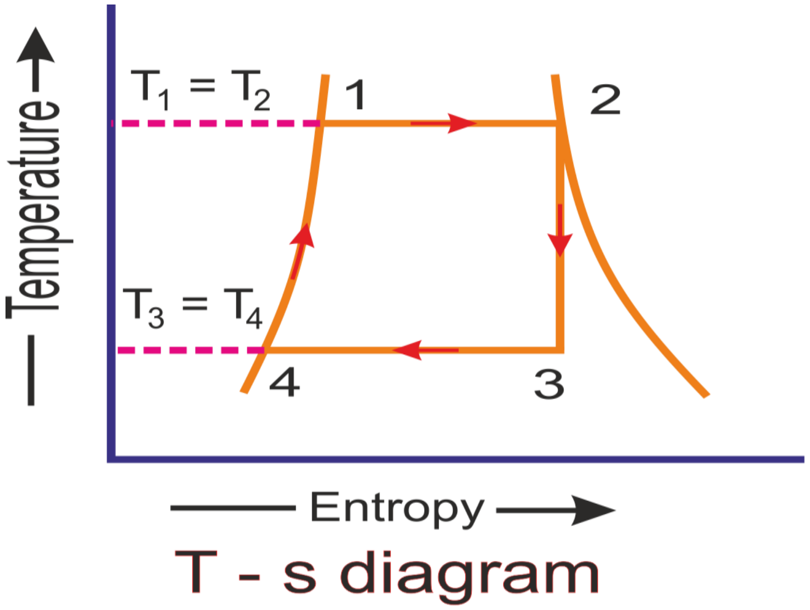
Rankine cycle is nothing but a modification of Carnot cycle.Ideal Rankine cycle is very useful in steam power plants and gas power plants. To improve the efficiency of Rankine cycle in the steam power plant, there are some changes in Rankine cycle which differs fromthe Carnot cycle. Firstly, a pump is used in place of condenser to handle only liquid, not a mixture of liquid and vapour. Secondlycc, exhaust steam from the turbine is completely condensed in the condenser, see in the following



diagram

It is a reversible process. The **Rankine cycle efficiency** is much higher than Carnot cycle efficiency as because the pump is used in the Rankine cycle, which gives higher work ratio by doing significant proportion of turbine work.





A simple ***Rankine cycle*** is completed by following four processes. Steam is used as a working substance in Rankine cycle, is shown the above p-v Rankine cycle diagram and T-s Rankine cycle diagram.

1).**Process 1-2:**
As we see in the above diagram, saturated water coming from hot well ata point 1 is isothermally converted into dry saturated steam in a boiler and heat is absorbed at constant temperature T_1 and pressure p_1. The steam is now dry condition showing at point 2. The temperature and pressure at point 2 is T_2 and p_2 respectively. It is similar to the T_1 and p_1. This isothermal expansion process shown in the p-v and T-s curve 1-2. During isothermal expansion process, the heat absorbed by water denotes h_{fg1} which is similar to the h_{fg2} as a corresponding pressure p_1 and p_2.(since $p_1 = p_2$)

2).**Process 2-3:**

Now the dry saturated steam enters into the turbine. Here steam expands isentropically and the pressure and temperature falls down from p_2 to p_3 and T_2 to T_3 with a dryness fraction x_3. During this expansion, no heat is supplied or rejected. So, there is no change in entropy and curve from 2-3 falls down show the above graph.

3).**Process 3-4:**
At this stage, Wet steam enters the condenser for condensation of steam. Heat is rejected in the condenser at a constant temperature T_3 and pressure p_3 until the total steam is condensed into water. At point 4 conditions, $T_3 = T_4$. So the curve of the p-v and T-s diagram is straight line and heat is rejected by steam is called latent heat equal to $x_{3}h_{fg3}$
4).**Process 4-1:**
Now water enters to the boiler at point 4 positions for warming. In the boiler, water is heated to a constant temperature T_4 to T_1 and volume. The pressure rises from p_4 to

p_1. This operation is shown in the graph 4-1 on p-v and T-s diagram. The heat absorbed by water during this operation is equal to the sensible heat or liquid heat corresponding to the pressure p_1 which is equal to sensible heat at point 1 minus sensible heat at point 4

Let,

$h_{f1} = h_{f2}$ = Sensible heat or enthalpy of water at point 1 corresponding pressure p_1 or p_2 (since $p_1 = p_2$)

$h_{f4} = h_{f3}$ = Sensible heat or enthalpy of water at point 4 corresponding pressure p_4 or p_3 (since $p_4 = p_3$)

So, Heat absorbed at warmed operation 4-1 = $h_{f1} = h_{f4} = h_{f2} = h_{f3}$

and heat absorbed during the complete cycle is

$= h_{fg2} + (h_{f2} - h_{f3}) = h_{f2} + h_{fg2} - h_{f3} = h_{f2} - h_{f3}$

We know that heat rejected during the cycle

$= h_3 - h_{f4} = h_{f3} + x_3h_{fg3} - h_{f4} = x_3h_{fg3}$

Wordhunter during the cycle is = Heat absorbed - heat rejected

$= (h_2 - h_{f3}) - x_3h_{fg3}$

$= h_2 - (h_{f3} + x_3h_{fg3})$

$= h_2 - h_3$

So, rankine cycle efficiency η_R is –

$$\eta_R = \frac{Work\ done}{Heat\ Absorbed} = \frac{h_2 - h_3}{h_2 - h_{f3}}$$

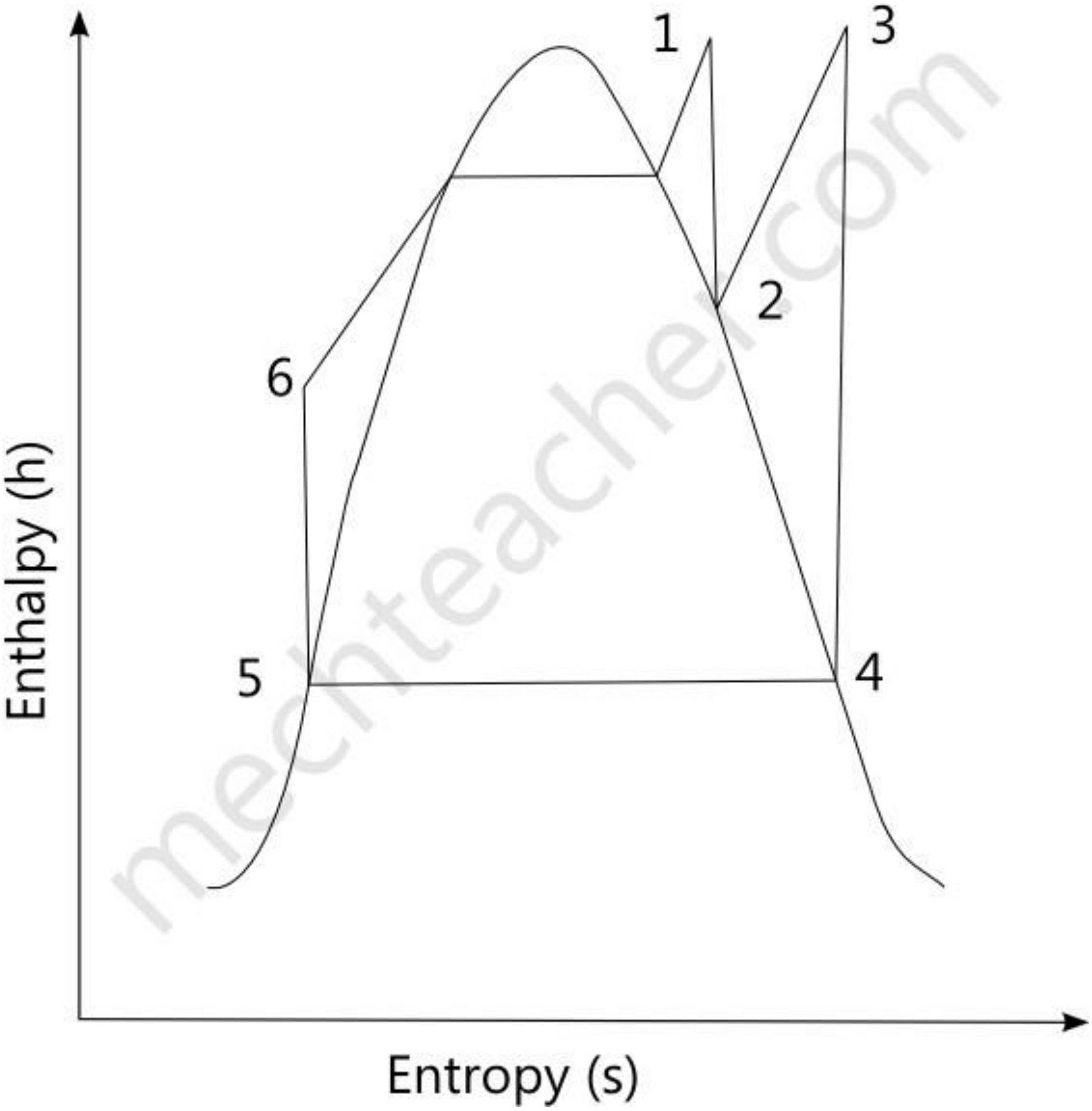
v

What is Reheat Rankine cycle

In simple rankine cycle, after the isentropic expansion in turbine , steam is directly fed into condenser for condensation process. (Refer this article for better understanding). But in reheat system, two turbines (high pressure turbine and low pressure turbine) are employed for improving efficiency. Steam, after expansion from high pressure turbine, is sent again to boiler and heated till it reaches superheated condition. It is then left to expand in low pressure turbine to attain condenser pressure.

h-s diagram of Reheat Rankine Cycle:

Reheat Rankine cycle can be understood well if you refer the following h-s diagram:



Processes in Reheat Rankine Cycle:

Six processes take place in reheat Rankine cycle. They are explained in detail below:

Process: 1-2 (high pressure turbine)

Here, dry saturated steam from the boiler is allowed to expand in a turbine isentropically i.e., Entropy remains constant.

Let h_1 be the enthalpy of steam entering the turbine
Let h_2 be the enthalpy of steam leaving the turbine
Finally, the work done by turbine is given by

$W_T = h_1 - h_2$

Calculation of h_1 and h2 :

Using the pressure and temperature values at point 1, values for entropy (S_1) and enthalpy (h_1) can be calculated from superheated steam table or from Mollier diagram for steam.
After finding h_1 and S_1 ,dryness fraction (x_2) can be calculated using the formula given below,

$$S1=S2=Sf2+x2\times Sfg2$$

Substitute the value of x_2 in the following equation to find h_2,

$$h2=hf2+x2\times hfg2$$

Process: 2-3 (boiler)

The expanded steam is made to attain the required temperature i.e., reheated in low pressure boiler at constant pressure level. The enthalpy (**h_3**) and entropy (**S_3**) are calculated by the same method that we followed in process 1 to 2.

Process: 3-4 (Low pressure Turbine)

After attaining required temperature, steam is passed into low pressure turbine to carry out the remaining expansion. The enthalpy (**h_4**) and entropy (**S_4**) values are calculated by the same method that we followed in process 1 to 2 .

Process: 4-5 (condenser)

After expansion in turbine, steam is passed into condenser to preform condensation process. Here the remaining heat in the steam is rejected into atmosphere.

Let h_4 be the enthalpy of steam entering the condenser.
Let h_5 be the enthalpy of water leaving the condenser.
Heat rejected from condenser is given by

$Q_R = h_4 - h_5$ J or $Q_R = h_2 - h_{f4}$ J
$h_{f4} = h_4$ (Since, the output from condenser is a fluid and graphically, the enthalpy at point 4 and point 5 are same.)

Process: 5-6 (Pump)

Water from the condenser is pumped into the boiler using an external pump. During this process, pressure increases P_5 to P_6 isentropically (The enthalpy and temperature of water also increase due to pump work).
Let P_5 ,h_5 be the pressure and enthalpy at stage 5 respectively.
Let P_6 ,h_6 be the pressure and enthalpy at stage 6 respectively.
The work done by pump is given by

$W_p = h_6 – h_5 = V_{f5} (P_6 – P_4) \times 100$ J

Note :
All the values of pressure here are substituted in N/m² and all values of enthalpy are substituted in Joules.

Process: 6-1 (boiler)

Here the saturated water from the pump is heated by using a constant heat source (such as furnace). The input saturated water is heated till it reaches super-heated condition. Temperature and enthalpy of saturated water raise to a great extent, but its pressure remains constant. The change of phase from liquid to vapour occurs in boiler.

Let h_6 be the enthalpy of saturated water entering the boiler.
Let h_1 be the enthalpy of super-heated steam coming out of boiler.
Heat supplied is given by

$Q_S = h - h_6$ J
h_6 can be calculated by means of pump work done formula.
$h_6 = h_5 + W_p$ J
All processes can be understood well if you refer the h-s diagram above.

Efficiency of Reheat Rankine Cycle:

As we know, efficiency is the ratio between output and input. Here, the output is work done and input is heat energy.

Net workdone = workdone in turbine (both H.P. turbine and L.P. turbine) + workdone in pump .

Net heat transfer = heat supplied in boiler + heat rejected in condenser.

Efficiency of reheat Rankine cycle is given by:

$\eta reheat=(h1-h2)+(h3-h4)-WPh1-(h5+Wp)+(h3-h2)$

Boiler Accessories:-

• A boiler requires many accessories for continuous troublegeneration.
• Some accessories are needed to increase the efficiency of the boiler.
• High economy in power generation can be achieved by utilizing the heat enemaximum extent.
Some of the essential boiler accessories
as follows,
1. Super heater
2. Re heater
3. Economizer
4. Air pre heater

1. Super heater:-

• As the name implies, the the boiler.
• The steam generated in a boiler is not fully saturated, it contains some water particles (Dryness fraction will be less than 1).
• If used directly, the water particles in the wet steam cause corrosion of the turbine blades, lead to reduced turbine efficien
• The super heater completely saturates the wet steam (produces dry steam) and increases its temperature.
• A superheated steam has high heat content, and hence has an increased capacity to do work.
• This in turn improves the overall efficiency of the power plant.
• The super heaters are made of steel tubes of 25 to 50 mm diameter, and formed in series of U
shapes.
• Super heaters can be classified based on the heat transfer method.
• There are three types of super heaters, as follows:
trouble-free functioning and steam

Useful for waste heat recovery, in the sequence, are include:-
Function of a super heater is to superheat the steam coming from efficiency, life and later failure of the blade energy to thecy

a) Convective super heater

• Absorbs heat from the hot gases by convection.
• This is the primary super heater that receives nearly saturated steam from the boiler drum.
• This super heater is located in the convective zone of the furnace, just before the economizer.

b) Radiant super heater -

• Absorbs heat from the hot gases
• This is the secondary super heater that receives steam from the primary super heater.
• This super heater is located in the radiant zone of the furnace, adjacent to tile water wall so that it absorbs heat by radiation.

c) Combined convective and radiant super heater

• Absorbs heat both by convection and radiation from the hot gases.
• This is also termed the pendant super heater, and is another secondary super heater used in steam power plants.
• Usually the steam from the rad
quality water is directly sprayed on to the steam.
• The de super heater maintains the required temperature in the steam after passing through the
final stage or the pendant super heater.

2. Re-heater:-

• In a boiler, the super heaters are used to superheat the steam before being expanded in the high pressure (HP) turbine.

• The steam from the HP turbine loses the pressure and temperature.
• This steam before being sent to the next stage (intermediate IP or low pressure LP) turbine, it
need to be improved again, this is done by passing this steam through a re heater.
• Thus, a re-heater is similar to a super heater, except that it adds heat to
the HP turbine, before being expanded in the IP or LP turbine.
• A re heater is generally located above the primary or convective super heater in the path of the hot
flues.
• It is made of steel tubes mounted horizontally, perpendicular to the flue direction.

3. Economizer:-

• The function of an economizer is to heat the feed water, before being supplied to the boiler, using the products of combustion discharged from the boiler.
• Generally feed water is heated 20
• The economizer makes use of waste flues; recovers heat energy and hence the name economizer.
• Thus the economizer increases the boiler efficiency.
• As an approximation, it is shown that the boiler efficiency increases by 1% for every 6°C raise in the feed water temperature
• The flues passing through the economizer chamber transfer the heat energy to the water flowing through the steel tubes.
• The maximum temperature desir
above 85°C the steam bubbles begin to form and the feed pump cannot supply steam mixture properly.
• To overcome this problem the feed water pump is generally located before the economizer.
• The feed water pump pumps either raw water (after proper treatment) or condensate from the
condenser.
• The feed water flowing through the economizer gets heated and enters the boiler under pressure.
• A non-return valve is provided to avoid return flow of f
when the feed pump is not in operation.
• The pump pressure is always higher (about 2 bar more) the boiler pressure in operation.

Advantages of Economizer

1) It recovers the waste heat to a greater extent.
2) It reduces the fuel consumption per unit power produced.
3) It improves the efficiency of the power plant.
*4) It reduces the soot and fly*20-30°C below the boiling point.
ee

4. Air pre heater:-

• The function of an air preheater, as the name indicates, is to preheat the air being supplied to
the furnace for combustion.

- This makes use of the flues discharged from the furnace and from the economizer.
- As this also recovers further heat from the flue
- An increase in temperature of the 20°C increases the boiler efficiency by 1 %.

***Advantages*:-**

1) Combustion efficiency is improved.
2) Low grade fuels can be burnt successfully.
3) Steam rising capacity is increased.
4) Fuel consumption is reduced.

Cooling Towers:-

The different types of cooling towers used in power plants are:
1. Wet type
a) Natural draught cooling tower
b) Forced draught cooling tower
c) Induced draught cooling tower
2. Dry type
a) Direct type
b) Indirect type

1. Wet type:-

a) Natural draught cooling tower

• This is a wet type of cooling tower, and is generally used in large capacity power plants.
• It consists of a huge hyperbolic concrete structure, with openings at the bottom.
• At the lowest portion of the structure a water pond is constructed for the collect cooling water.

b) Forced draught cooling tower

• Forced draught cooling towers are smaller in size and are used in small capacity power plants.
• Since the height of the cooling tower is smaller and it has a rectangular section, the natural draught created very low.
• Hence, to create a draught, a forced draught a fan is provided at the bottom
• The cooling tower is a rectangular section having baffles
• A forced draught fan is provided at the bottom, and it pressurizes the air.
• The hot water from the condenser is sprayed from the top and while falling through the baffles/obstacles it comes in contact with the raising forced dr
• The cooled water is collected in the pond and re circulated.
• Make up water is added to the pond periodically

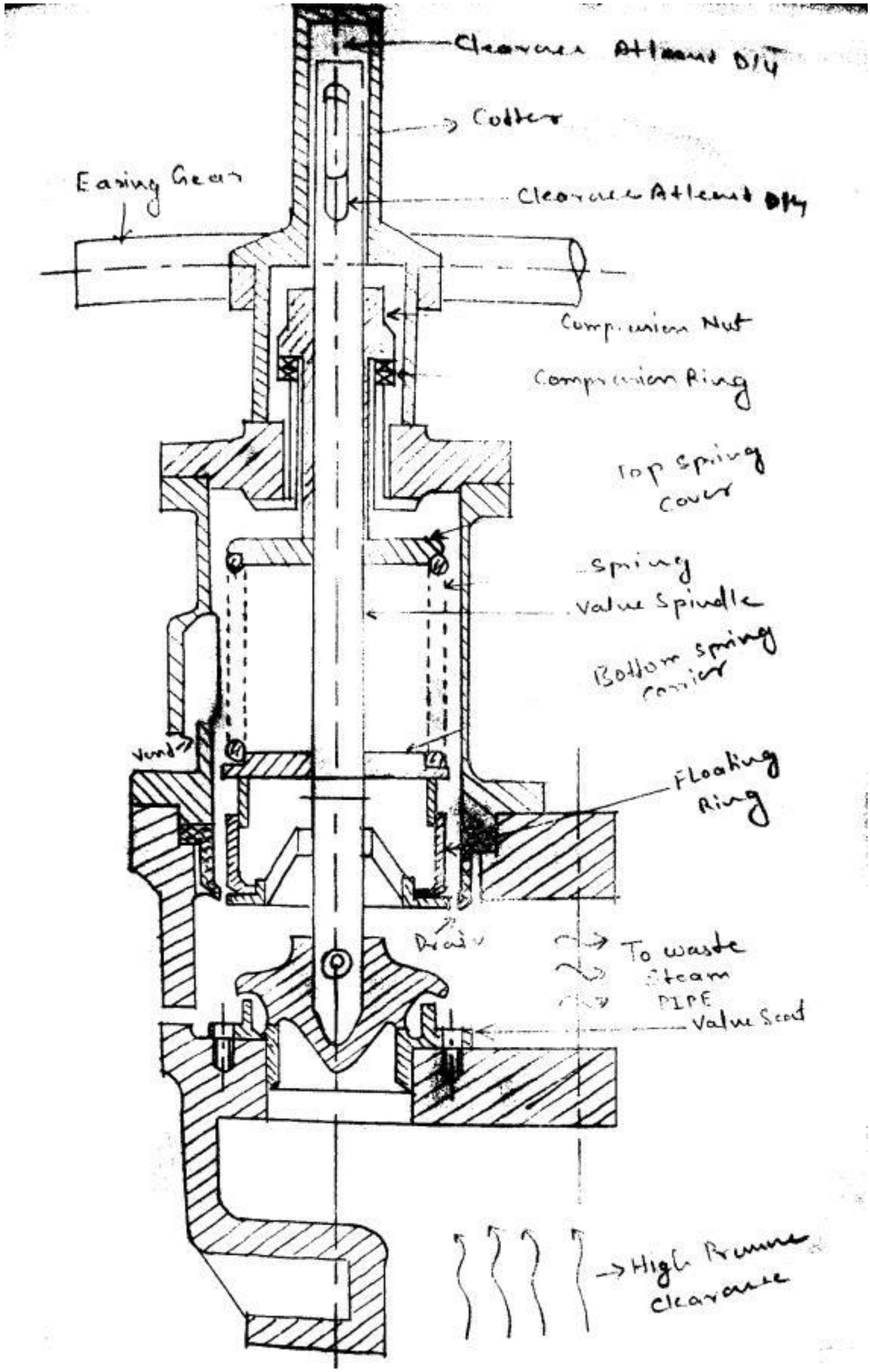
c) Induced draught cooling tower

• This is similar in construction and operation to a forced draught cooling tower, induced draught fan.
• This is suitable for small capacity power plants.
• It has a rectangular section with opening at the bottom for the air entry.

• In operation the induced draught fan sucks air through the baffles from the openings at the bottom of the tower.
• The hot water pumped from the condenser is sprayed at the top.
• The falling water comes in contact with the raising air and gets cooled.
• The cooled water is collected in the pond and pumped back to the condenser.

Boiler Mountings

Regular accidents and boiler break down can happen due to improper maintenance and cleaning. Without boiler mounting one can damage boiler and its surrounding with one mistake by a series of events. Without high lift safety valve the shell could explode resulting into great loss of life and machinery; similarly a shell could collapse under vacuum if air vent is not present during cooling down. During cargo operation there is a increased demand for steam and so the mountings help operate the boiler with more and ease and safety. Boiler mountings include:

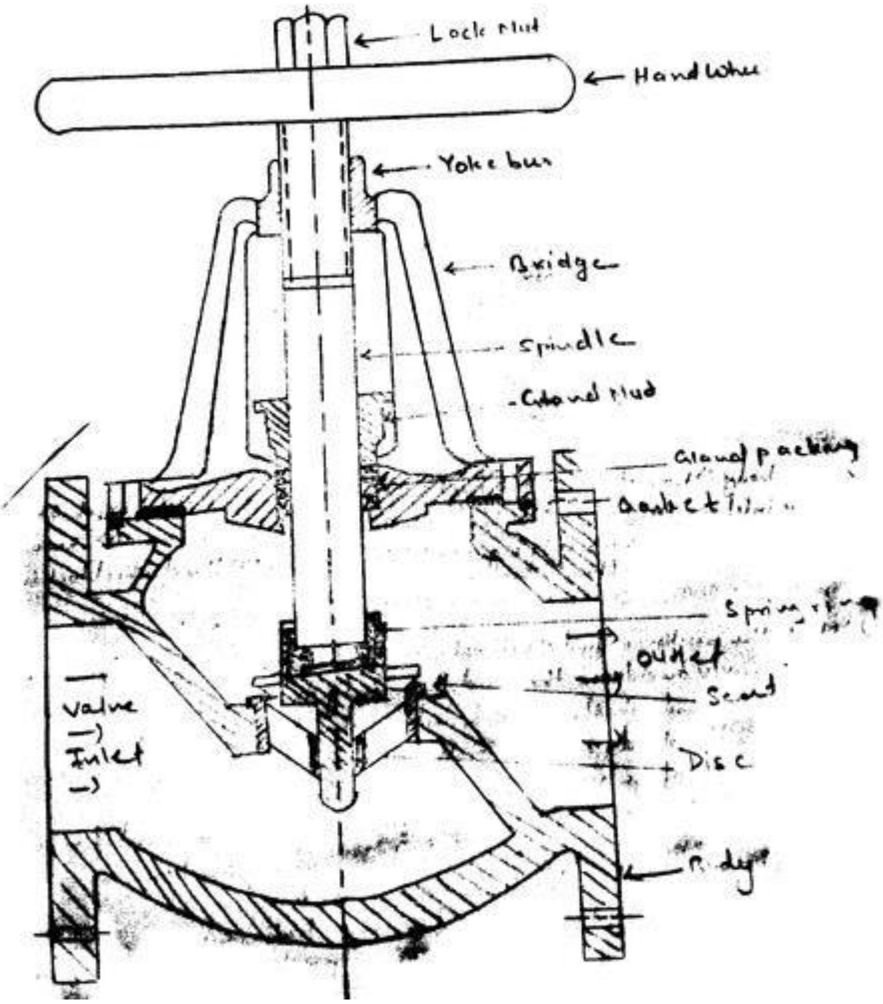


Boiler Safety Valve

1) Safety Valves

Safety valves are fitted on every boiler to avoid over pressurizing. Normally three safety valves are fitted on the boiler with one on the super heater and rest two on steam drum. In no condition these valves be less than two in number and must lift at a pressure 3% above boiler working pressure irrespective of boiler types.

A steam valve is made up of cast iron body with two independent valves fitted on the valve seat. These valves are connected to a lever by means of a pivot held tight to its position by spring. The spring force keep the valve sit shut on the valve seat under normal condition. When the upward pressure exceeds the downward spring force; the valve is lifted and excess steam is released to the atmosphere.



Steam Stop valve

2) Steam Stop valve

A steam stop valve is connected to the boiler to stop and regulate steam flow from boiler to the distribution lines. Main steam stop valve on boiler is kept shut to avoid back-flow of steam to the boiler. The flange of the steam stop valve is bolted on top of the steam drum. Valve main body is made of cast iron while the valve seat is made from gun metal. The spindle on one end is connected to the valve while the other end to the handle wheel passing through (yoke / Gland nut) and gland packing. The valve is operated by rotating the hand wheel. Rotating hand wheel in turn rotate the spindle which move the valve up allowing path for steam to flow.

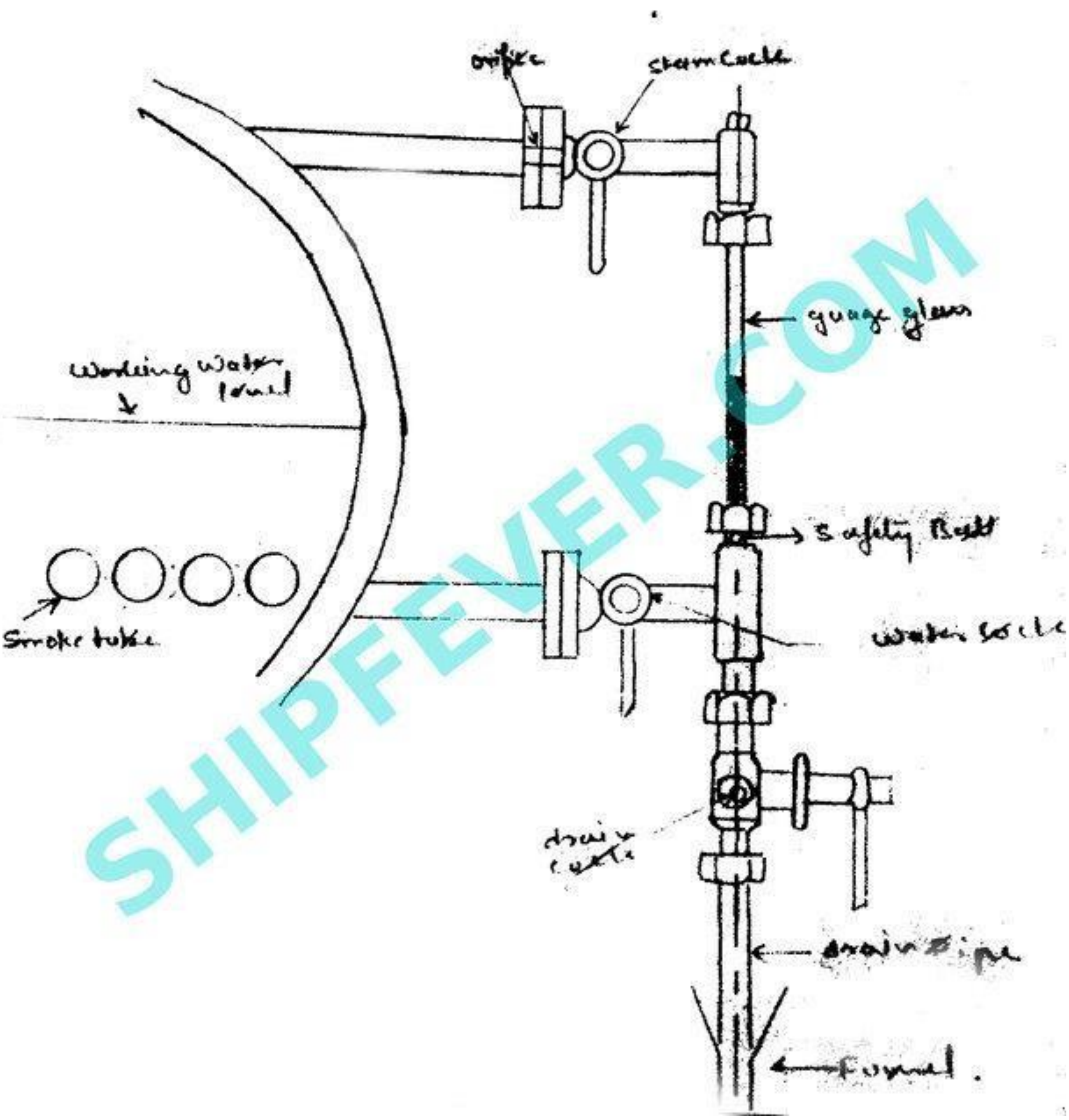
3) Vent Valve

Vent valve is installed on the boiler shell to vent air from steam drum during starting of boiler. These vent valves also comes handy during boiler shut down as it let fresh air to enter the boiler drum avoiding its collapse under pressure. A vent valve can also be used to release / dump moist steam at start.

Boiler Pressure gauge (Boiler Mountings)

4) Pressure Gauge

Pressure gauge are fitted to the steam drum and super heater to indicate steam pressure inside. These gauge are fitted on the front top of the boiler shell and represent pressure in bar. A bourdon tube of closed cross section is attached to the steam space on one end through siphon tube. The tube itself contain water to avoid steam to enter into the pressure gauge. The pointer is connected to the threaded gear attached to the spindle. When pressure is applied to the bourdon tube it becomes circular turning the spindle. This cause the pointer to move along with the gear; representing the boiler pressure.



Boiler Gauge Glass (water level indicator)

5) Water Level Indicator

A pair of water level indicator is installed directly to the boiler shell with an additional remote reading gauge installed at convenient position. They are installed directly on the front end of all boiler types; showing water level in boiler drum. It consist of a glass tube with three independent cock (Steam cock, water cock and drain cock).

Steam and water cock separates the glass tube with boiler steam and water respectively. Drain cock on other hand used to drain water from glass tube. A metal ball is provided on the water side of the gauge glass to avoid subsequent accident and water loss; by water flashing off steam in event of glass rapture / failure.

Under normal condition both steam and water cock is open allowing water and steam pressure to balance. In event of incorrect reading we need to blow through; by closing the water cock and opening drain cock. A strong blow will indicate the steam cock is clear; now repeat the process with steam cock closed and water cock opened. Strong blow of steam with hissing sound indicate the water cock is clear. Now close the drain cock and let water fill in; slowly open the steam cock equalizing the pressure.

Boiler Draught :-

➢ The draught is one of the most essential systems of thermal power plant which supplies requiredquantity of air for combustion and removes theburnt products from the system

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.

➢ This difference of pressure for to maintaining theconstant flow of air and discharging the gasesthrough the chimney to atmosphere is known asDRAUGHT.

Types Of Draught :-

➢Natural Draught

➢Artificial Draught

Natural Draught :-

► The Draught required for the flow of air & gas inside the boiler is created by Chimney

► It does not require any external power for producing the draught.

► The capital investment is less.

► It has long life.

Limitations Of Natural Draught :-

- Pressure :- maximum is 15 – 20 mm of water under normal atmospheric Temp.
- The draught decreases with increase in outside air temperature and for producing sufficient draught.
- The flue gases have to be discharged at comparatively high temperatures resulting in the loss of overall plant efficiency. And thus maximum utilization of Heat is not possible.
- Combution is very poor.

Artificial Draught :-

- Because of insufficient head and lack offlexibility, The use of natural draught is limited tosmall capacity boilers only.
- The draught required in actual power plant issufficiently high (300 mm of water) and to meethigh draught requirements, some other systemmust be used which are known as artificialdraught.

Classification of ArtificialDraught :-

1. Forced
2. Induced
3. Balanced

Advantages over naturaldraught :-

- It is better in control and more economical than natural draught.
- The rate of combustion is high.
- The air flow can be regulated according to the requirement.
- It prevents the formation of smoke as complete combustion is possible

Limitations of Artificial Draught:-

- The major disadvantage of the artificial draught is the high capital cost required and high running andmaintenance costs.

Importance:-

- For the proper and the optimized heat transfer from the flue gases to the boiler tubes draft holds a relatively highamount of significance.
- The combustion rate of the flue gases and the amount of heat transfer to the boiler are both dependent on themovement and motion of the flue gases.
- A boiler equipped with a combustion chamber which has a strong current of air (draft) through the fuel bed will increase the rate of combustion.

STEAM CONDENSER

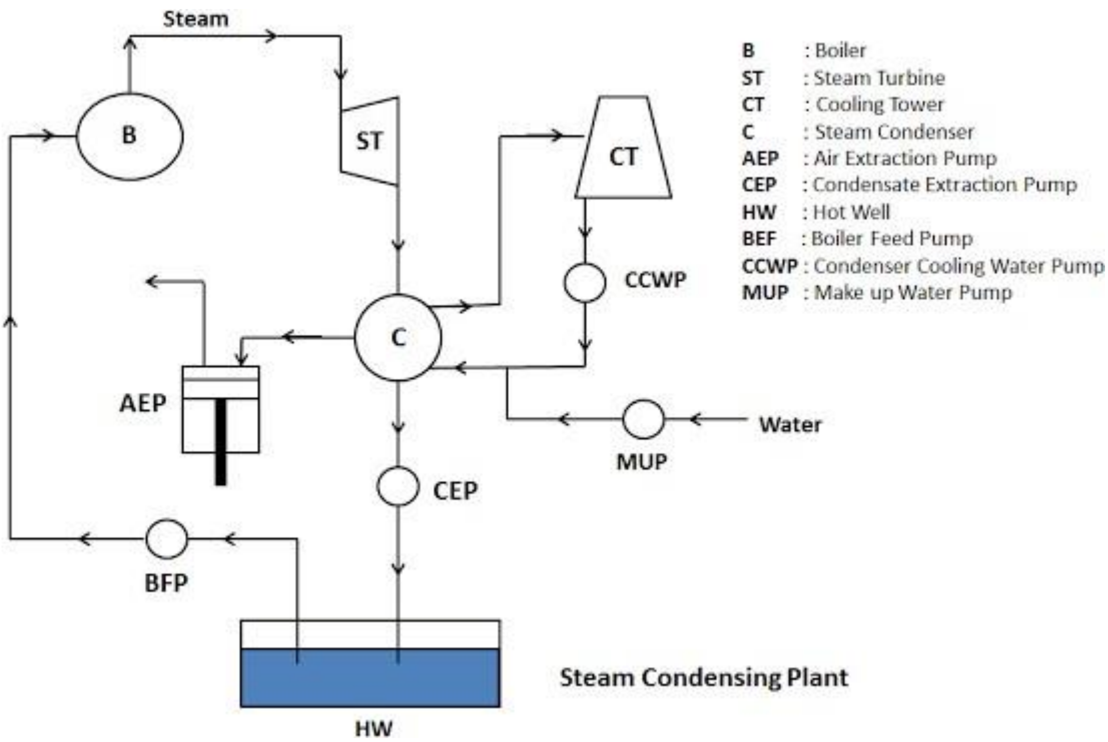
Definition, Working, Types and Advantages

Steam Condenser is a mechanical device which converts the low pressure exhaust steam from the turbine into water. Or in other words it is a device which is used to condense exhaust steam of the turbine into water. It does so with the help of cooling water circulated into it from the cooling tower.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.

Requirements of Steam Condensing Plant

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 its heat to the 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. Air Extraction Pump: It is a pump used to extracts or removes the air from the steam condenser.

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

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

Working

The steam condenser receives the exhaust steam from one end and comes in contact with the cooling water circulated within it form the cooling tower. As the low pressure steam comes in contact with the cooling water, it condenses and converts into water. It is connected to the air extraction pump and condensate extraction pump. After the condensation of steam, the condensate is pumped to the hot well with the help of condensate extraction pump. The air extraction pump extracts the air from the condenser and creates the vacuum inside it. The vacuum created helps in the circulation of cooling water and flow of condensate downward.

Classification of Steam Condenser

The steam condenser is classified as

1. Jet condensers or mixing type condenser
2. Surface condenser or non-mixing type condenser

Jet Condenser

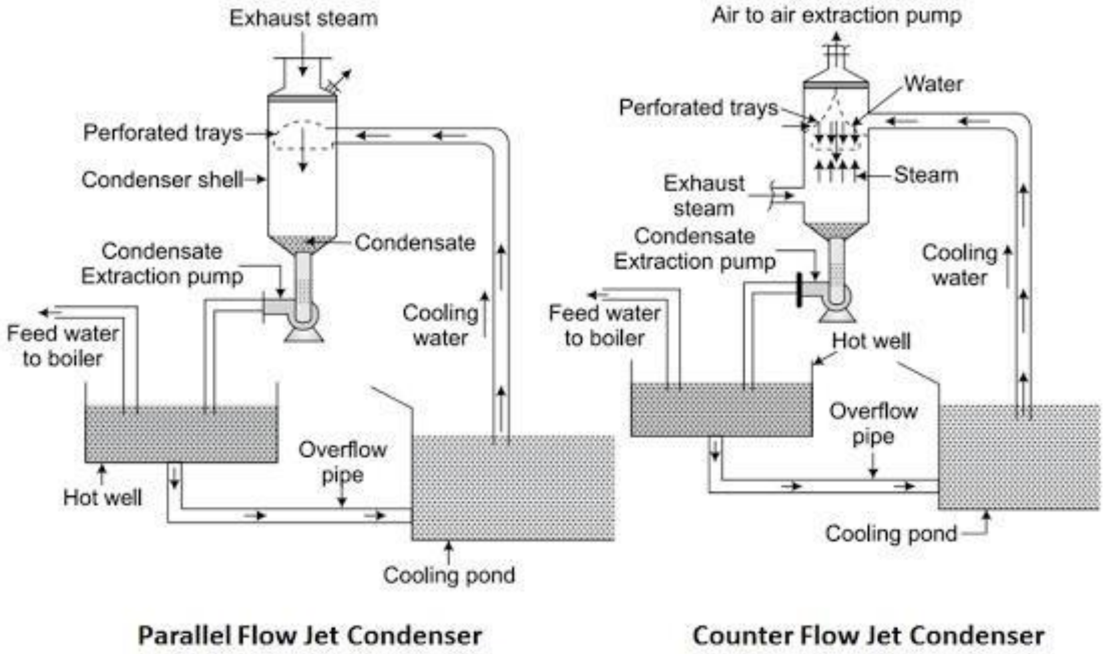
Jet condenser is a condenser in which the condensate gets mixed with the cooling water. That’s why it is also called as mixing type condenser.

This type of condenser is used sometime because it lost some of the condensate and requires high power for the pump during the process of condensation.

In jet condenser, as the condensate is not free from the salt, so it cannot be used as feed water for the boiler. It can be used at the place where sufficient amount of good quality water is available.

Types of Jet Condenser

(i) Parallel Flow Jet Condenser



In parallel flow jet condenser, the steam and water enters into the condenser at the top and leaves at the bottom.

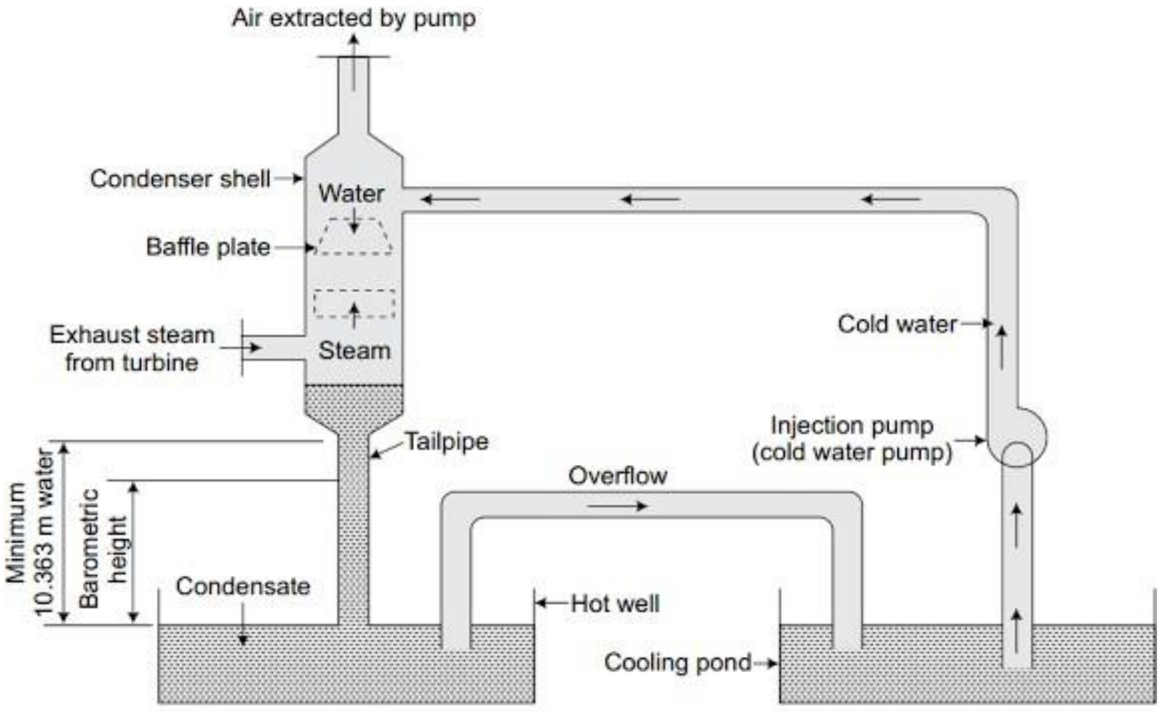
The cooling water and steam enters at the top. As both steam and cooling water mix with each other, the steam gets condense. The condensate, cooling water and air moves downward and it is removed by two separate pumps known as air extraction pump and condensate extraction pump. The condensate pump transfers the condensate to the hot well and from there the extra water is made to flow in cooling water tank or pond through overflow pipe.

(ii) Counter Flow or Low Level Jet Condenser

In counter Flow or low level jet condensers, the steam enters at the bottom and the cooling water at the top. The steam flows upward and meets the cooling water coming downward.

In these types of steam Condensers, the air pump is located at the top. Air pump creates vacuum and this vacuum draws water from the cooling tower. The cooling water enter into the condenser and falls on the perforated conical plate. The perforated conical plates convert the cooling water into a large number of jets as shown in the figure. The falling jet of water caught in the trays and from there it escapes out in second series of jets and meets the exhaust steam entering at the bottom. As the steam mix with the water, it gets condense. The condensate and cooling water moves down through a vertical pipe to the condensate pump. And finally the pump delivers it to the hot well.

*(iii) **Barometric or High Level Jet Condenser***

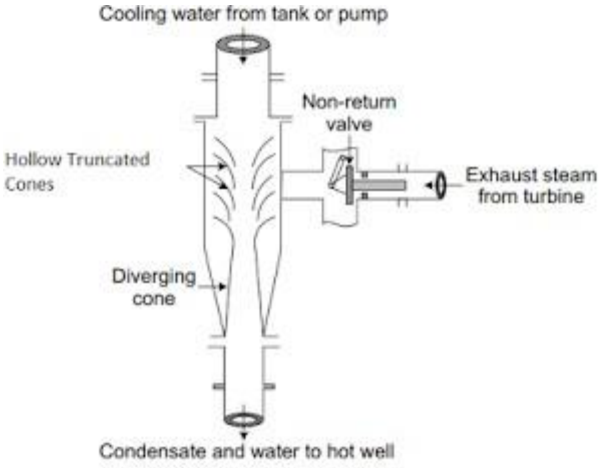


Barometric or High Level Jet Condenser

Barometric or high level jet condensers are provided at high level with a long vertical discharge tube or tailpipe. It does not have condensate extraction pump and the condensate and cooling water flows in the hot well because of the gravity. An injector pump is used to flow cooling water at the top of the condenser.

These types of jet condensers are used at a high level with a vertical discharge pipe. In this condenser, the steam enters at the bottom and flows in upward direction and meets with the down coming cooling water. Its working is similar as the low level jet condenser. The vacuum is created at the top of the condenser shell. With the help of vacuum and injector pump, the cooling water is moved to the top of the condenser. The condensate and cooling water comes down in the hot well through a long vertical discharge pipe. And finally the extra hot water flows to the cooling tank or cooling pond by an overflow pipe

(iv) Ejector Condenser

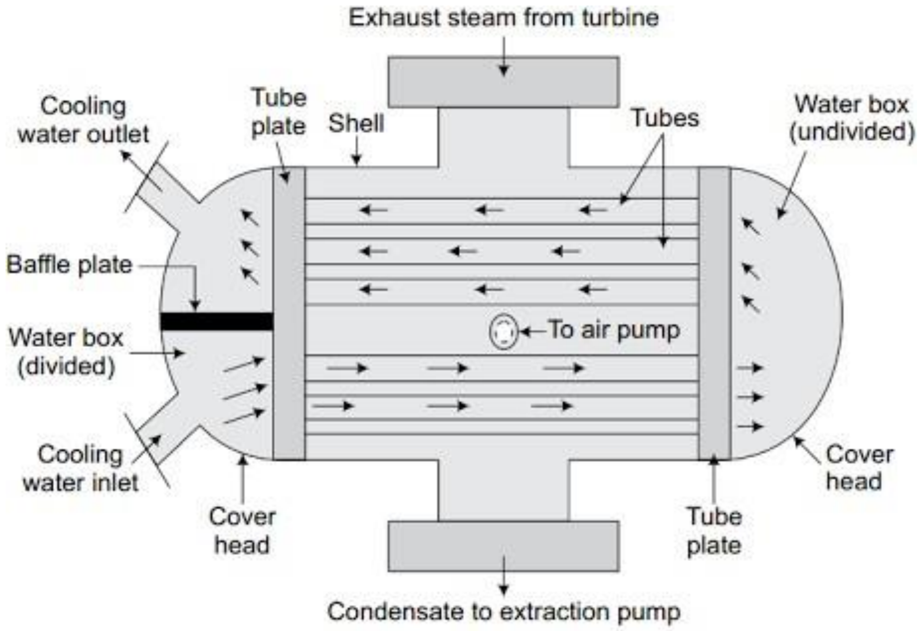


Ejector Condenser

In ejector condensers, it has a non-return valve through which exhaust steam enters, hollow truncated cones, and diverging cone.

In these condensers, the cooling water is injected at the top. The steam enters into the condenser through a non-return valve. The steam and water mixes with each other while passing through series of hollow truncated metal cones and steam changes into water. At the end of the metal cones a diverging cone is present. When the condensate passes through diverging cone, its kinetic energy is partly transformed into pressure energy.
The condensate and cooling water is then discharged to the hot well.

Surface Condensers



Surface Condenser

Surface condenser is a type of steam condenser in which the steam and cooling water do not mix with each other. And because of this, the whole condensate can be used as boiler feed water. It is also called as non-mixing types condenser.

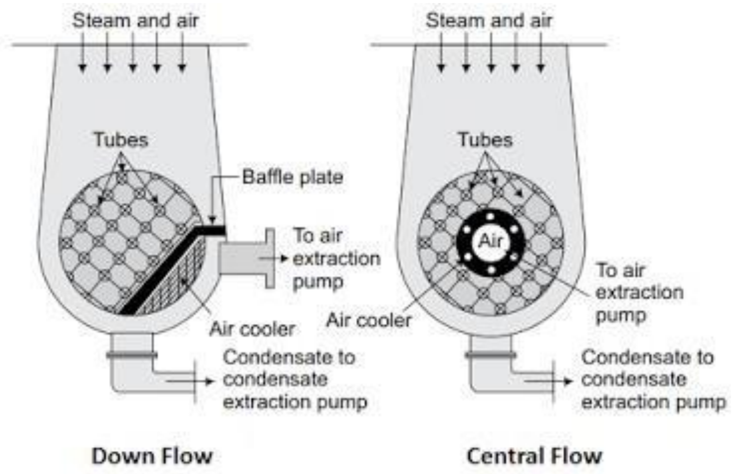
The figure above shows the longitudinal section of a two pass surface condenser. It consists of a horizontal cylindrical vessel made of cast iron and packed with tubes. The cooling water flows through these tubes. The ends of the condensers are cut off by the perforated type plates. The tubes are fixed into these perforated type plates. It is fixed in such a manner that any leakage of water into the center of condensing space is prevented. The water tubes are passed horizontally through the main condensing space. The exhaust steam from the turbine or engine enters at the top and forced to move downward due to the suction of the air extraction pump. In this steam condenser, the cooling water enters into boiler through lower half of the tubes in one direction and returns in opposite direction through the upper half as shown in the figure above.

This type of condenser is used in ships as it can carry only a limited quantity of water for the boiler. It is also widely used for the land installation where there is a scarcity of good quality of water.

Types of Surface Condensers

The surface condenser on the basis of direction of flow of condensate, the arrangement of the tubing system and the position of the extraction pump are classified as

i) Down Flow



In Down flow surface condenser, the steam enters at the top of the condenser and flows downwards over the tubes due to the gravity and air extraction pumps. The condensate gets collected at the bottom and then pumped with the help of condensate extraction pump. The pipe of dry air extraction pump is provided near the bottom and it is covered by baffle plates so as to prevent the entry of the condensate into it.

The steam in down flow condenser flows perpendicular to the direction of flow of cooling water, so it is also called as cross-surface condenser.

(ii) Central Flow

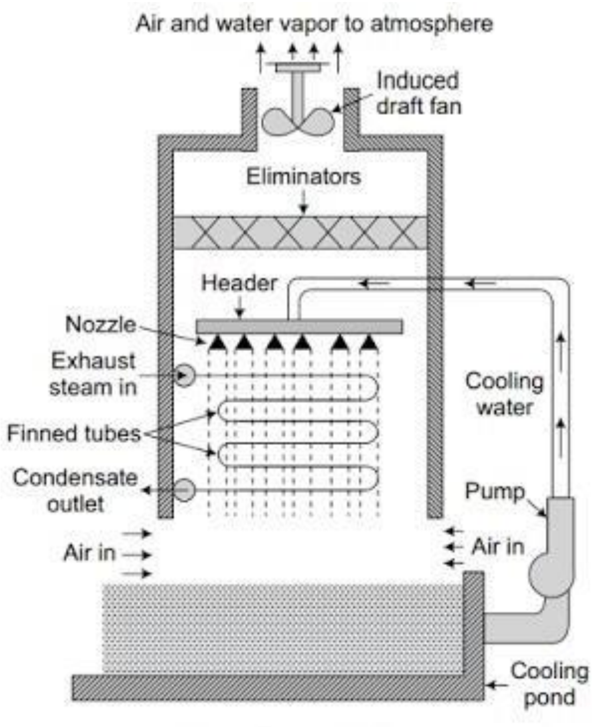
In central flow condenser, the steam enters at the top of the condenser and flows in downward direction. In this the suction pipe of the air extraction pump is provided in the center of the tube nest as shown in the figure. Due to this placement of the suction pipe in the center of the tube nest, the exhaust steam flows radially inward over the tubes towards the suction pipe. The condensate is collected at the bottom of the condenser and pumped to the hot well.

We can say that it is the improved form of the down flow surface condenser.

(iii) Regenerative

In regenerative surface condensers, the condensate is heated by the use of regenerative method. In that the condensate is passed through the exhaust steam coming out from the turbine or engine. This raises its temperature and it is used as the feed water for the boiler.

(iv) Evaporative



Evaporative Condenser

In evaporative surface condensers, the steam enters at the top of the condenser in a series of pipes over which a film of cold water is falling. At the same time, current of air is made to circulate over the film of water. As the air circulates over the water film, it evaporates some of the cooling water. As a result of this rapid evaporation, the steam circulating inside the series of pipes gets condensed. Remaining cooling water that left is collected at an increased temperature and reused. It is brought to the original temperature by adding required quantity of cold water.

Advantages of Steam Condenser

- It increases the efficiency of the plant.
- It reduces the back pressure of the steam and as a result of this, more work can be done.
- It reduces the temperature of the exhaust steam and this allows to obtain more work.
- It allows the reuse of condensate for the feed water and hence reduces the cost of power generation.

- The temperature of the condensate is more than the feed water. This reduces the supply of heat per kg of steam.

Comparison of Jet and Surface Condenser in Tabular Form

S.no	Jet Condenser	Surface Condenser
1.	Exhaust steam and cooling water mixed with each other.	Exhaust steam and cooling water are not mixed with each other.
2.	It is less suitable for high capacity plants.	It is more suitable for high capacity plants.
3.	The condensing plant using this type of steam condenser is simple and economical.	The condensing plant using surface condenser is costly and complicated.
4.	Condensate is wasted and cannot be reused.	The condensate is reused.
5.	Less quantity of circulating water is required.	Large quantity of circulating water is required.
6.	It has low maintenance cost.	It has high maintenance cost.
7.	In jet condenser, more power is required for the air pump.	In surface condenser, less power is required for the air pump.
8.	High power is required for water pumping.	Less power is required for water pumping.

Advantages of gas turbine engines

- Very high power-to-weight ratio, compared to reciprocating engines;
- Smaller than most reciprocating engines of the same power rating.
- Moves in one direction only, with far less vibration than a reciprocating engine.
- Fewer moving parts than reciprocating engines.
- Low operating pressures.
- High operation speeds.
- Low lubricating oil cost and consumption.

Disadvantages of gas turbine engines

- Cost is much greater than for a similar-sized reciprocating engine since the materials must be stronger and more heat resistant. Machining operations are also more complex;
- Usually less efficient than reciprocating engines, especially at idle.
- Delayed response to changes in power settings.

These disadvantages explain why road vehicles, which are smaller, cheaper and follow a less regular pattern of use than tanks, helicopters, large boats and so on, do not use gas turbine engines, regardless of the size and power advantages imminently available.

Steam Turbine Basic Parts

In this article, we will discuss steam turbine basic parts. The steam turbines are widely used in power generation, refineries and petrochemical industries.

- **Turbine Casings**
-

The casing shape and construction details depend on whether it is a High Pressure(HP) or Low Pressure (LP) casings. For low and moderate inlet steam pressure up to 120 bar, a single shell casing is used. With a rise in inlet pressure the casing thickness as to be increasing. Handling such heavy casing is very difficult also the turbine as to slowly brought up to the operation temperature. Otherwise undue internal stress or distortions to the thick casing may arise. To over this for high pressure and temperature application double casing is used. In the double casing inner casing is for High pressure and the outer casing is for hold the low pressure.

COMPOUNDING OF STEAM TURBINE

THERE ARE THREE TYPES OF COMPOUNING

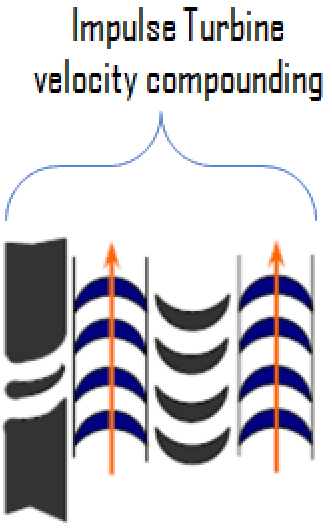
1.VELOCITY COMPOUNDING.

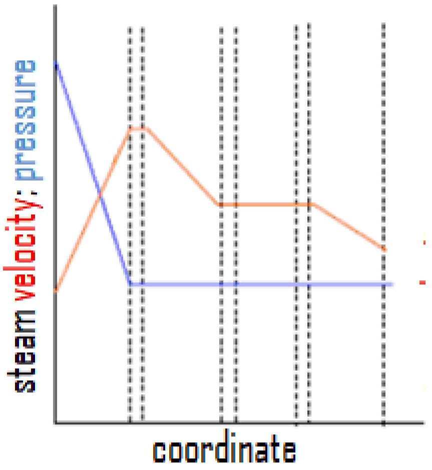
2.PRESSURE COMPOUNDING.

3.PRESSURE AND VELOCITY COMPOUNDING.

1.VELOCITY COMPOUNDING.

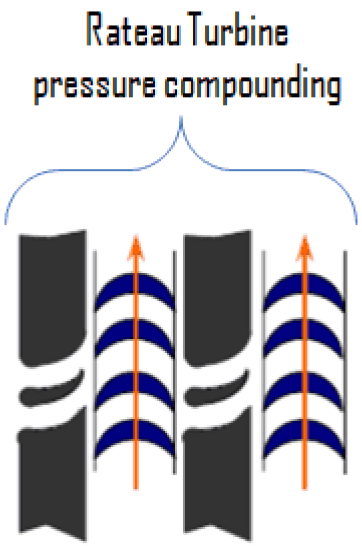
velocity-compounded impulse stage consist of a **row of fixednozzles** followed by **two or more rows of moving blades** and **fixed blades** (without expansion). This divides the velocity drop across the stage into several smaller drops. In this type, the total pressure drop (expansion) of the steam take place only in the **first nozzle ring**. This produces **very high velocity steam**, which flows through multiple stages of fixed and moving blades. At each stage, only a portion of the high velocity is absorbed, the remainder is exhausted on to the next ring of fixed blades. The function of the fixed blades is to redirect the steam (without appreciably altering the velocity) leaving from the first ring of moving blades to the second ring of moving blades. The jet then passes on to the next ring of moving blades, the process repeating itself until practically all the velocity of the jet has been absorbed.
This method of velocity compounding is used to solve the problem of single stage impulse turbine for use of high pressure steam (i.e. required velocity of the turbine), but they are less efficient due to high friction losses.

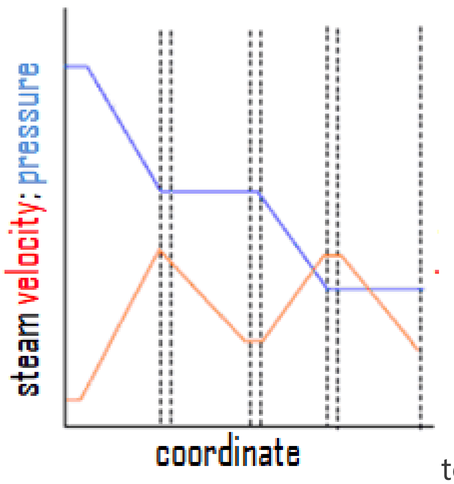




2.PRESSURE COMPOUNDING.

pressure-compounded impulse stage is a **row of fixed nozzles** followed by a **row of moving blades**, with multiple stages for compounding. In this type, the





total pressure drop of the steam does not take place in the first nozzle ring, but is divided up between all the nozzle rings. The effect of absorbing the pressure drop in stages is to reduce the velocity of the steam entering the moving blades. The steam from the boiler is passed through the first nozzle ring in which it is only **partially expanded**. It then passes over the first moving blade ring where nearly all of its velocity (momentum) is absorbed. From this ring it exhausts into the next nozzle ring and is again **partially expanded**. This method of pressure compounding is used in Rateau and Zoelly turbines, but such turbines are bigger and bulkier in size.

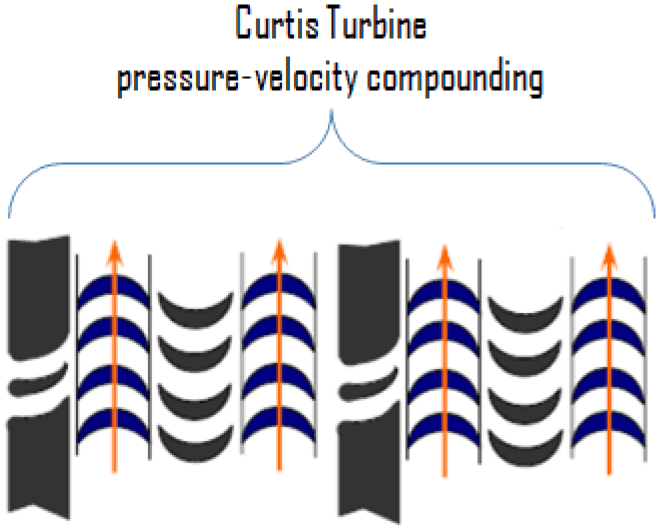
mpulse stages may be either pressure-compounded, velocity-compounded, or **pressure-velocity compounded**.

3. PRESSURE-VELOCITY COMPOUNDING.

The **pressure-velocity compounding** is a **combination** of the above two types of compounding. In fact, a series of velocity-compounded impulse stages is called a pressure-velocity compounded turbine. Each stage consists of rings of fixed and moving blades. Each set of rings of moving blades is separated by a single ring of fixed nozzles. In each stage there is one ring of fixed nozzles and 3-4 rings of moving blades (with fixed blades between them). Each stage acts as a velocity compounded impulse turbine.

The steam coming from the steam generator is passed to the first ring of fixed nozzles, where it gets **partially expanded**. The pressure partially decreases and the velocity rises correspondingly. It then passes over the 3-4 rings of moving blades (with fixed blades between them) where nearly all of its velocity is absorbed. From the last ring of the stage it exhausts into the next nozzle ring and is again partially expanded.

This has the advantage of allowing a bigger pressure drop in each stage and, consequently, less stages are necessary, resulting in a shorter turbine for a given pressure drop. It may be seen that the pressure is constant during each stage; the turbine is, therefore, an impulse turbine. The method of pressure-velocity compounding is used in the **Curtis turbine**.



STEAM TURBINE GOVERNING SYSTEM

Steam turbine governing system is a method, used to maintain a constant steady speed of turbine. The importance of this method is, the turbine can maintain a constant steady speed irrespective of variation of its load. A turbine governor is provided for this arrangement. The purpose of the governor is to supply steam into the turbine in such a way that the turbine gives a constant speed as far as possible under varying the load. So, basically **Steam turbine governing system** is a process where turbine maintains a steady output speed irrespective of variation of load. The different types of steam turbine governor of are:

1. Throttle Governing Of Steam Turbine

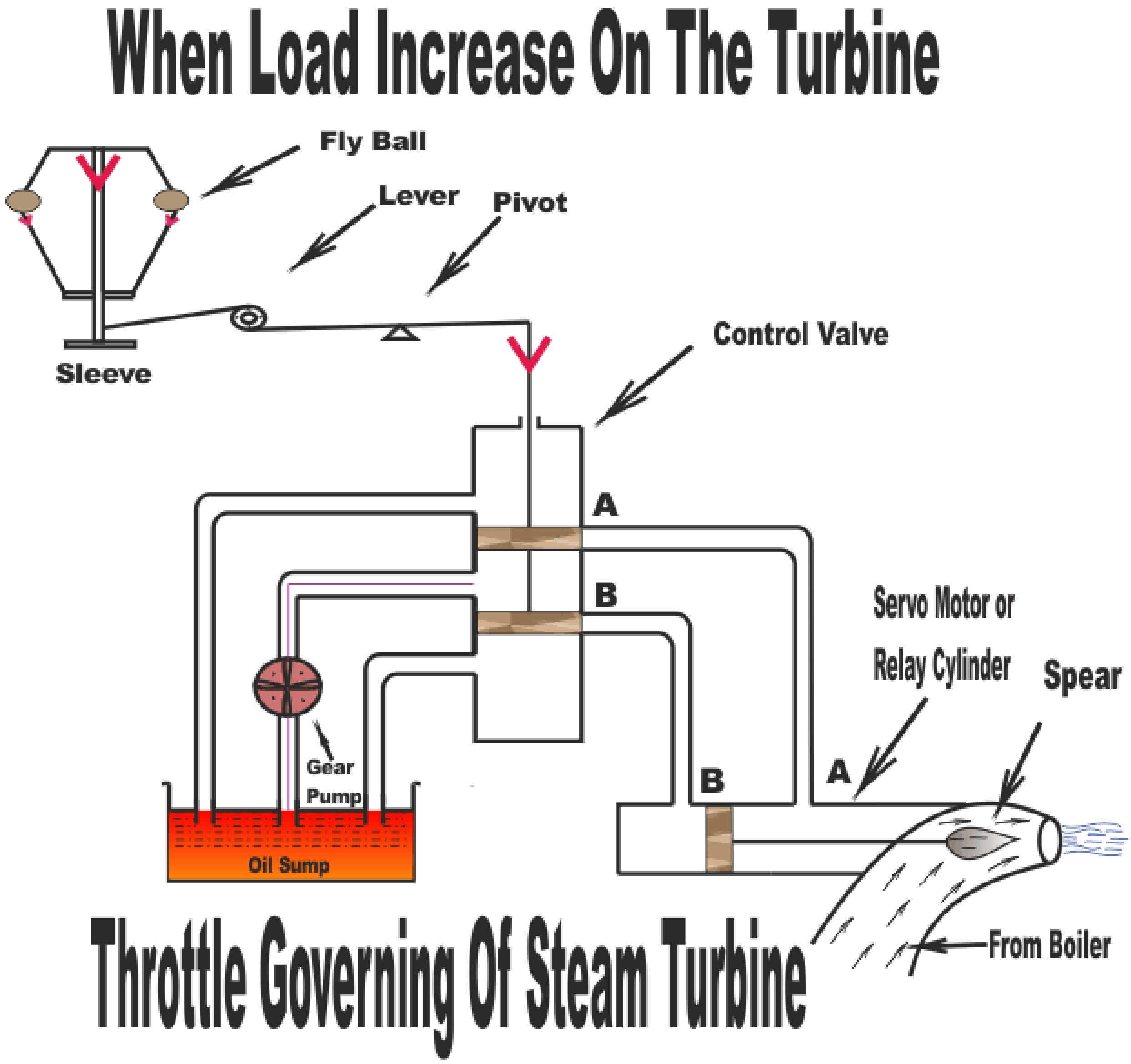
2. Nozzle Control Governing Of Steam Turbine

3. Bypass Governing Of Steam Turbine

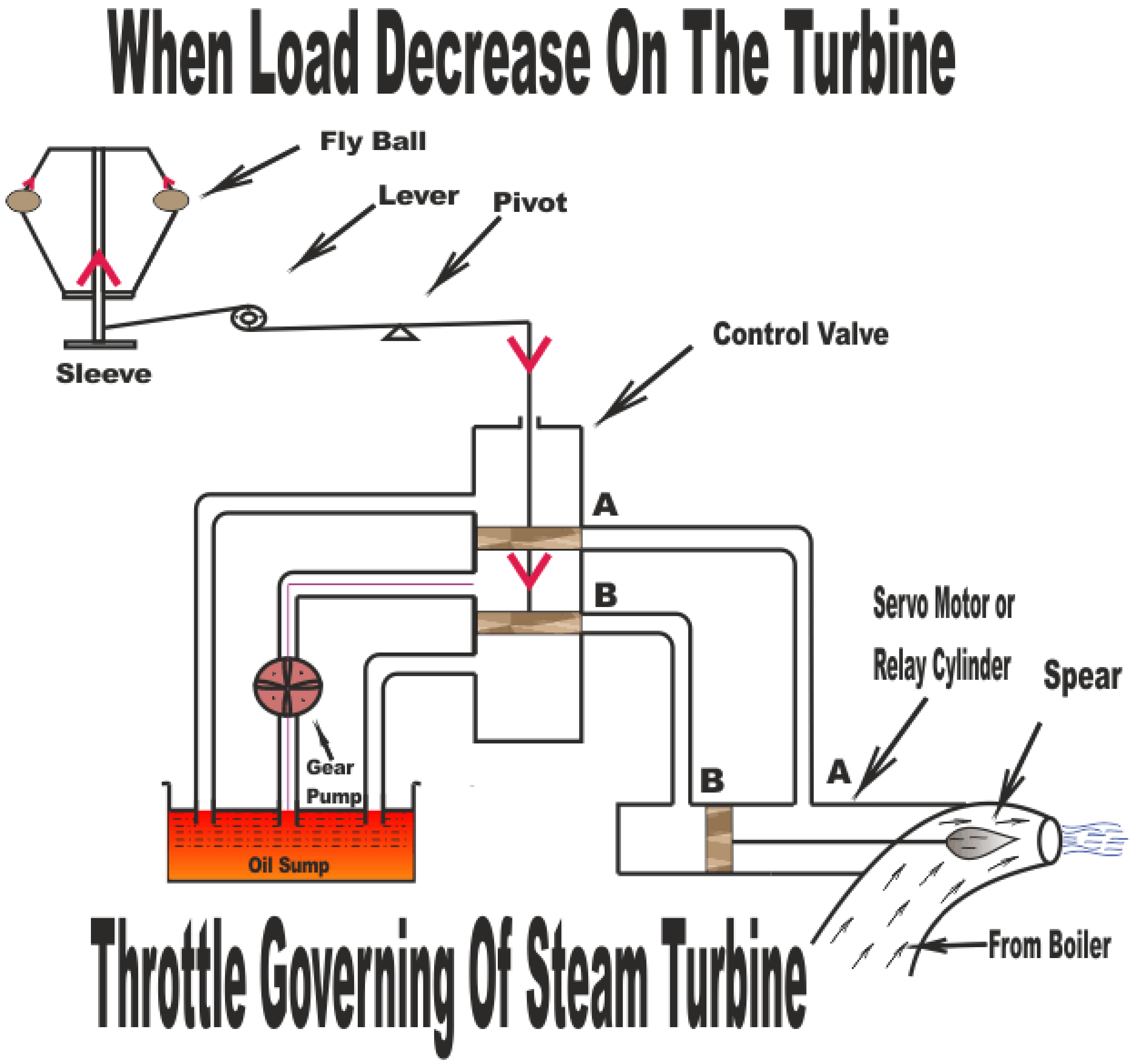
1. Throttle Governing Of Steam Turbine:-

Throttle Governing of steam Turbine is most popular and easiest way to control the turbine speed. When steam turbine controls its output speed by varying the quantity of steam entering the turbine is called Throttle Governing. It is also known as Servomotor methods.

In this system, a centrifugal governor is driven from the main shaft of turbine by belt or gear arrangement. A control valve is used to control the direction of oil flow which supplied by the pipe AA or BB. The servomotor or relay valve has a piston which moves towards left or right depending upon the pressure of oil flow through the pipes AA or BB. This cylinder has connected a needle which moves inside the nozzle.When the turbine is running at normal speed, everything in the turbine such as such control valve, servomotor, piston position, fly balls of centrifugal governor will be in their normal position as shown in the figure. The mouth of both pipes AA or BB is closed into the control valves.



Assume that the turbine's load increases. It will decrease its speed which will decrease the centrifugal force of the turbine. Now fly balls of the governor will come down thus decreasing their amplitude. These fly balls also bring down the sleeve. The sleeve is connected to a control valve rod through a lever pivoted on the fulcrum. This down word sleeve will raise the control valve rod. Now oil is coming from the from the oil sump, pumped by gear pump is just stay at the mounts of both pipes AA or BB which are closed by the two wings of control valves. So, raise of control valve rod will open the mouth of the pipe AA but BB is still closed. Now the oil pressure is coming from the pipe AA. This will rush from the control valve which will move the right side of the piston. As a result, the steams flow rateinto the turbine increases which will bring the speed of the turbine to the normal range. When speed of the turbine will come to its normal range, fly balls will come into its normal position. Now, sleeve and control valve rod will back to its normal position.



2. Nozzle Control Governing Of Steam Turbine:-

It is another interesting method by which turbine's speed can be controlled. Nozzle control governing of steam turbine is basically used for part load condition. Some set of nozzles are grouped together (may be two, three or more groups) and each group of the nozzle is supplied steam controlled by valves. Every valve is closed by the corresponding set of nozzle. Steam's flow rate is also controlled by these nozzles. Actually, nozzle control governing is restricted to the first stage of turbine whereas the subsequent nozzle area in other stage remains constant. According to the load demand, some nozzles are in active and other inactive position. Suppose turbine holds ten numbers of nozzles. If the load demand is reduced by 50% then five numbers of nozzles are in open condition and rest is closed. This method is suitable for SIMPLE IMPULSE TURBINE. It is a process where rate of steam flow is regulated depending on the opening and closing of set of nozzles rather than regulating its pressure.

3. Bypass Governing Of Steam Turbine:-

Bypass governing of steam turbines a method where a bypass line is provided for the steam. Especially this is used when turbine is running in overloaded condition. The bypass line is provided for passing the steam from first stage nozzle box into a later stage where work output increase. This bypass steam is automatically regulated by the lift of valve which is under the control of the speed of the governor for all loads within its range. Bypass valve is open to release the fresh stem into the later stage of the turbine. In the later stage output, work is increased and the efficiency is low due to the throttle effect.

Thermal Efficiency of Steam Turbine

In general the **thermal efficiency, η_{th}**, of any heat engine is defined as the ratio of the work it does, **W**, to the heat input at the high temperature, Q_H.

$$\eta_{th} = \frac{W}{Q_H}$$

The **thermal efficiency**, η_{th}, represents the fraction of **heat**, Q_H, that is converted **to work**. Since energy is conserved according to the **first law of thermodynamics** and energy cannot be be converted to work completely, the heat input, Q_H, must equal the work done, W, plus the heat that must be dissipated as **waste heat** Q_C into the environment. Therefore we can rewrite the formula for thermal efficiency as:

$$\eta_{th} = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

This is very useful formula, but here we express the thermal efficiency using the first law in terms of enthalpy.

. Stage efficiency:

A stage is defined as the combination of a ring of nozzles (fixed blades) and a ring of moving blades. The energy supplied corresponds to the isentropic heat drop, ΔH in the nozzles. The stage efficiency, ηs is given by,

ηs=work doneenergy supplied per stageηs=work doneenergy supplied per stage

The stage efficiency becomes equal to the blade efficiency if there are no friction losses in the nozzles. Thus,

ηs=ηn×ηbηs=ηn×ηb

2. **Blade efficiency**

The energy supplied per stage of an impulse turbine is equal to kinetic energy given by ηb=ṁC2i2ηb=ṁCi22 and assuming that the kinetic energy leaving the stage is wasted.
Blade efficiency can be defined as,

ηb=workdone on the bladesK.E supplied to the bladeηb=workdone on the bladesK.E supplied to the blade

Blade efficiency can also be defined as,

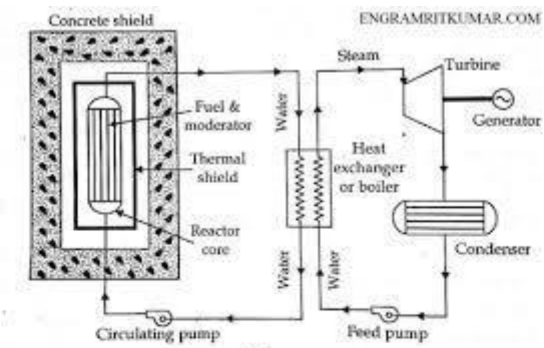
ηb=change in K.E.ofsteamK.Esuppliedηb=change in K.E.ofsteamK.E supplied

Blade efficiency will be maximum when C0C0 (Absolute velocity of steam at exit to moving blades) is minimum, that is, when β=90oβ=90o, or the discharge is axial.

COMPOUNDING:

CHAPTER..3

NUCLEAR POWERPLANT..



Nuclear power plant

LAYOUT OF NUCLER POWER PLANT.

General Structure of Nuclear power plant

The main components of the power plant:
1. Reactor vessel (Shielding)
2. Moderator
3. Control rod
4. Fuel rod
5. Coolant
6. Reflector

1. Reactor vessel (Shielding)

• It is a strong steel container in which the fuel rods, moderator, control rods and the reflector are arranged properly.
• It forms a strong structural support for the reactor core.

2. Moderator:

• **It is used to reduce the kinetic energy of fast neutrons into slow neutrons and to increase**
the probability of chain reaction.
• Graphite, heavy water and beryllium are generally used as moderator
• The hydrogen moderator would slow the neutron from **2MeV** to **0.025eV.**
• A moderator should possess the following properties:
i. It should have high thermal conductivity
ii. It should be available in large quantities in pure form
iii. It should have high melting point in case of solid moderators and low melting point in case of liquid moderators.
iv. Solid moderators should also possess good strength and machinability.
v. It should provide good resistance to corrosion.
vi. It should be stable under heat and radiation.
vii. It should be able to slow down neutrons.

3. Control rod:

• **Control rod is to regulate the rate of a chain reaction**.
• They are made of boron, cadmium or other elements which absorb neutrons.
• **Control rods should posses the following properties**,
i. They should have adequate heat transfer properties.
ii. They should be stable under heat and radiation.
iii. They should be corrosion resistant.
iv. They should be sufficient strong and should be able to shut down the reactor almost instantly under all conditions.
v. They should have sufficient cross sectional area for the absorption.

4. Fuel rods:

• **Fuel rod tube like structure containing Nuclear Fuels** .
• Nuclear fuels are made in the form of capsules & inserted in the tubes.
• During nuclear reaction nuclear fuel will release energy to produce power.
• **Important properties of Fuel rods,**
i. It should withstand high temperature.
ii. It should have high corrosion resistance.
iii. It should have good thermal conductivity.
iv. It should not absorb neutrons.
v. It should withstand radiation effects.

5. Coolant:

• **Coolants are used to cool the reactor by carrying away the heat generated by the reactor**.
• There are many number of coolants are used some of them are water (H_2O), heavy water (D_2O), carbon-di-oxide (CO_2), liquid sodium (liq. Na), organic liquid etc.
• The coolants should have high latent heat of absorption.

6. Reflector:

• Function of the reflector is to minimize the neutron leakag
reactor.
• Graphite and Beryllium are generally used as reflectors.
• The important properties of good reflectors material are:
i. It should have good thermal conductivity
ii. It should have good corrosion resistance
iii. It should have high stability under high temperature and pressure conditions
iv. It should not absorb neutrons
v. It should have good reflectivity.

Nuclear Energy:-

• Nuclear energy is the energy trapped inside each atom.
• Heavy atoms are unstable and undergo nuclear
• Nuclear reactions are of two types,
1. Nuclear fission…the splitting of heavy nucleus
2. Nuclear fusion…the joining of lighter nuclei

1. Fission:

• Fission may be defined as the
fragments.
• The fission fragments are generally in the form of smaller atomic nuclei and neutrons.
• Large amounts of energy are produced by the fission process.
For eg.
When neutron is bombarded into Uranium
Xenon-140 & Strontium-94 with release of high energy in the form of neutron.
leakage by reflecting them back into the
reactions.
process of splitting an atomic nucleus into fission
Uranium-235 ($_{92}U^{235}$) it will split into smaller nuclei

2. Fusion:-

• It is defined as nuclear reaction **whereby two light atomic nuclei fuse or combine to form a single larger, heavier nucleus**.
• The fusion process generates tremendous amounts of energy.
• For fusion to occur, a large amount of energy is needed to overcome the electrical charges of the nuclei and fuse them together.
• Fusion reactions **do not occur naturally** on our planet but are the principal type of reaction found in stars.
• The large masses, densities, and high temperatures of stars provide the initial energies needed to fuel fusion reactions.
• The sun fuses hydrogen atoms to produce helium, subatomic particles, and vast amounts of energy.

Comparison of fission and fusion:-

Sl. No. Fission Fusion
1 Splitting of heavy nucleus **Joining** of light nuclei
2 Is a **chain reaction** Is not a chain reaction
3 Can be **controlled** c a n n o t be controlled
4 Radiations are very harmful W i l l n o t emit harmful

2. Thermal Utilization Factor:

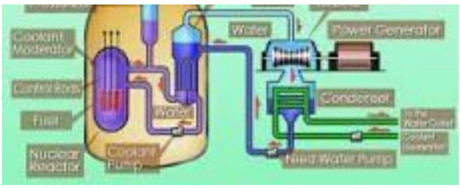
It is the thermal Neutrons absorbed in the fuel to the thermal Neutrons absorbed in the entire core.

Types of Reactor

Some of the reactors are,
1. Pressurized Water Reactor
2. Boiling Water Reactor
3. Liquid metal Fast breeder reactor or Sodium
4. Gas Cooled Reactor or Homogeneous graphite reactor

Pressurized Water Reactor(PWR)

FIG..



• In a PWR the primary coolant (natural
high pressure to the reactor core where it is heated from 275
energy generated by the
of about **155bar** in Primary circuit.
• The heated water then flows to a heat exchanger (steam generator) where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which, in turn, spins an electric generator.
• In contrast to a boiling water reacto
from boiling within the reactor. All PWRs use ordinary
neutron moderator.
• PWRs are the most common type of power producing nuclear reactor, and are widely used in
power stations such as ships and submarines all over the world.
• More than 230 of them are in use in
several hundred more for marine propulsion in aircraft carriers, submarines and ice breakers.

Advantages:

1. PWR reactors are very stable since they produce low power.
2. Less fissile material can be used hence safe

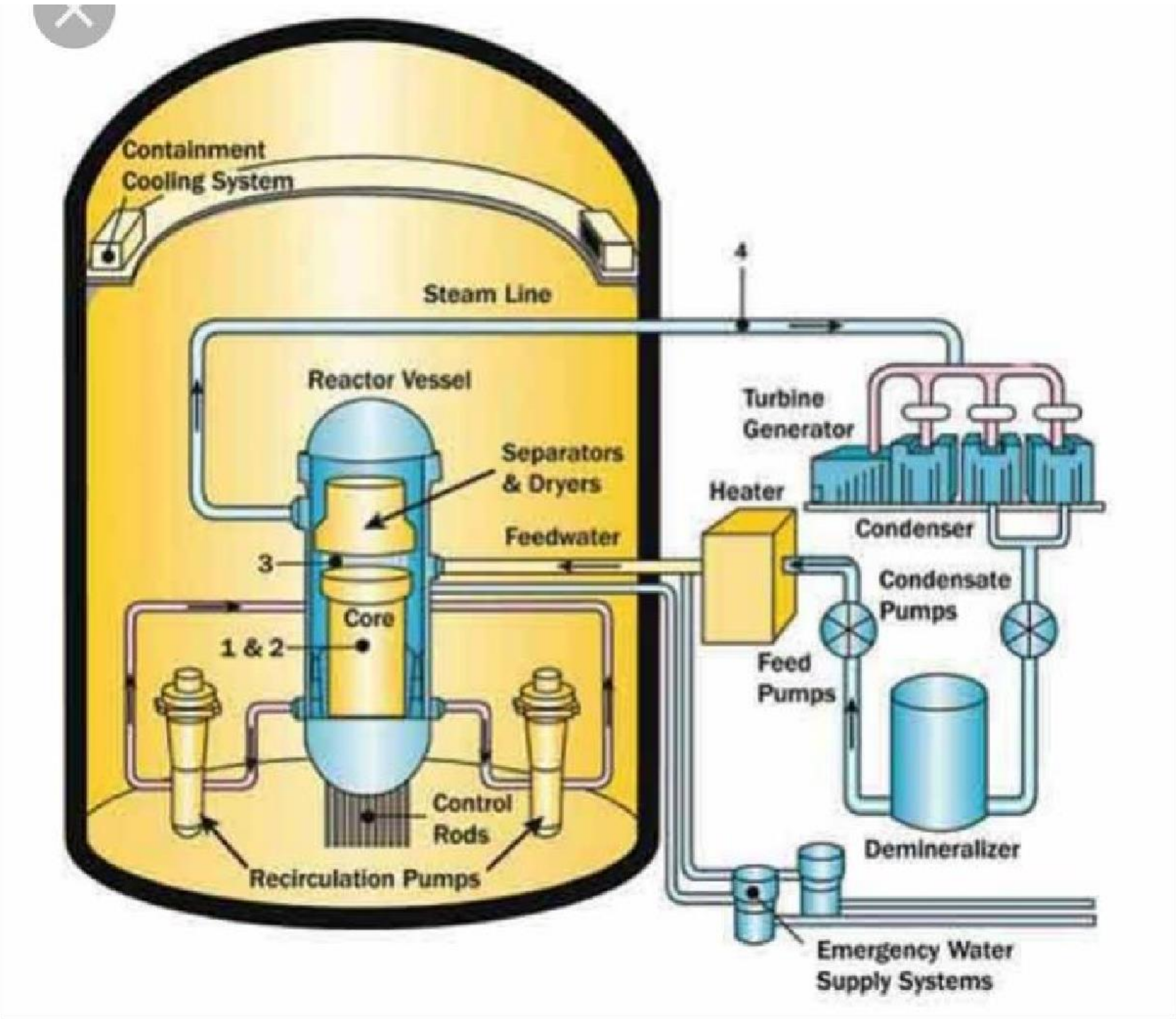
3. Ordinary water as coolant is easily available.
4. Small number of control rods is required.
5. Fission products remain contained in the reactor

Disadvantages:

1. Cannot be refueled while operating it will take long period of time (some week).
2. Severe corrosion problem.
3. High initial cost.
4. High maintenance cost.

2. Boiling Water Reactor (BWR)

Fig..



• Boiling water reactor (BWR) is the simplest of all facilities. Water absorbs heat from the reactions in the core and is directly driven to the turbines.
• After condensing the water is pumped back to the reactor core. In a Boiling Water Reactor **enriched fuel** is used.
• The BWR uses de mineralized water (
• Heat is produced by nuclear fission in the reactor core, and this causes the cooling water to boil, producing steam.
• The steam is **directly** used to drive converted back to liquid water. And highly enriched fuel or **water°C to 315fission** of atoms. Then it moves to a pressurizer to maintain pressure reactor, pressure in the primary coolant loop prevents the water**light water**
wer nuclear power plants to generate electric power, andsafe**.** And are not circulated.

Advantage:
1. Uses ordinary water as coolant, moderator which is easily available.
2. High thermal efficiency.
3. No need of Pressurizer.
4. Thicker vessel is not required.
5. Metal Temperature remains low.
6. Outlet temp of steam is very high.

Disadvantages:
1. Higher cost due to large pressure vessel.
2. Possibility of radioactive contamination in the turbine.
3. The possibility of "burn out" of fuel is more
4. More safety required.
5. Lower thermal efficiency.

Effects of Nuclear Radiation (Radiation Hazards):-

1] Effects on the tissues:-
Radiations affect the tissues in 3 ways,

a) Ionization: Ion pair in the tissue causes complete damage of tissues of man, animals, birds.

b) Displacement: Displacement of an atom of the tissue from its normal lattice position causes adverse effects on the tissues.

c) Absorption: This result in formation of a radioactive nucleus in the cell thus altering its chemical nature .It causes cell damage and genetic modifications.

2] Effects on the cells (biological effects):-
a) **Somatic effects**:
This results blood cancer, lung cancer, thyroid cancer, bone cancer.

b) Genetic effects:
This results still births, growth and developmental abnormalities

Comparision between nuclear and thermal ppt

Thermal Plant	Hydro Plant	Nuclear Plant
Located where water and coal and transportation facilities are adequate.	Located where large reservoirs or dams can be created like in hilly areas.	Located in isolated areas away from population.
Initial cost is lower than hydro and nuclear.	Initial cost pretty high due to large dam construction.	Initial cost is highest as cost of reactor construction is very high.
Running cost is higher than nuclear and hydro due to amount of coal required.	Practically nil as no fuel is required.	Cost of running is low as very very less amount of fuel is required.
Coal is source of power. So limited quantity is available.	Water is source of power which is not a dependable quantity.	Uranium is fuel source along with platinum rods. So sufficient quantity is available.
Cost of fuel transportation is maximum due to large demand for coal.	No cost for fuel transportation.	Cost of fuel transportation is minimum due to small quantity required.
Least environment friendly.	Most environment friendly.	Better friend of environment than steam power plant.
25% overall efficiency.	Around 85% efficient.	More efficient than steam power.
Maintenance cost is very high.	Maintenance cost is quite low.	Maintenance cost is the highest as highly skilled workers are required.
Maximum standby losses as boiler still keep running even though turbine is not.	No standby losses.	Less standby losses.

Radioactive Waste Disposal Systems:-

The main objective in managing and disposing of radioactive (or other) waste is to protect people and the environment Seal it inside a corrosion-resistant container, such as stainless steel. A possibility for long term storage on the earth is burial in the sea bed. The rock formations in the sea bed are generally more stable than those on dry land reducing the risk of exposure from seismic activity. As well there is little water flow under the sea bed reducing the possibility of radioactive material escaping into the ground water. High level radioactive waste is generally material from the core of the nuclear reactor or nuclear weapon. This waste includes uranium, plutonium, and other highly radioactive elements made during fission. There are three types of radioactive wastes.

a] Disposal of low level solid waste:

- Primarily the low level solid waste is cast in cement in steel drum.
- After it is buried few meters below from the soil or kept on ocean bed.
- It gets diluted as it disperses.

b] Disposal of medium level solid waste:

- These wastes mainly contaminated with neutron activation product isotopes.
- This type of waste is primarily put in a cement concrete cylinder.
- Then it is buried few meters below from the soil or kept on ocean bed.

c] Disposal of high level liquid waste:

- High level liquid waste is stored in steel cylinder tanks with concrete.
- It is water cooled to keep the temperature at 50°c.then this cylinder is stored in salt mine.
- The ocean is used for permanent storage of high level waste disposal.
- Long-term storage of radioactive waste requires the stabilization of the waste into a form which will not react, nor degrade, for extended periods of time. One way to do this is through **vitrification**.

CHAPTER..4
DIESEL ENGINE POWER PLANT

.

Application of diesel engine electric plant

(a) Peak load plants: Diesel plants can be used in combination with thermal or hydro plants as peak
load units. They can be easily started or stopped at short notice to meet the peak demand.
(b) Mobile plants: Diesel plants mounted on trailer can be used for temporary or emergenc purposes such as supplying power to large civil engineering works.
(c) Standby unit: If the main unit fails or can't cope up with demand, a diesel plant can supply
necessary power. For example, if the water available in the hydro plant is not adequately ava due to less rainfall, the diesel station can operate in parallel to generate short fall of power.
(d) Emergency plant: During power interruption in a vital unit like key industrial plant or hospital, a
diesel electric plant can be used to generate the
(e) Nursery station: In the absence of the main grid, a diesel plant can be installed to supply power
in a small town. In course of time when electricity from main grid becomes available in the town,
the diesel unit can be shifted to some other
station is called nursery station.
(f) Starting station: Diesel units can be used to run auxiliaries (like FD & ID fans) for starting large
steam power plant.
(g) Central station: Diesel electric plant can be usmall.

Layout of a diesel power plant

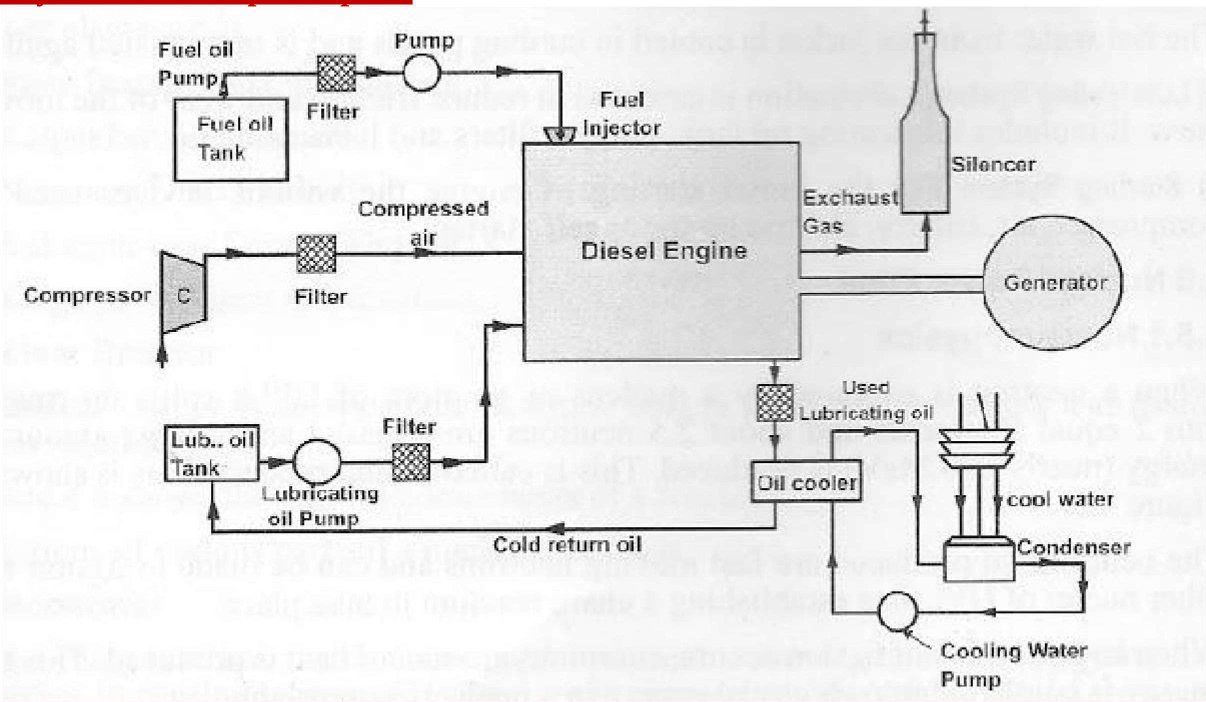


FIG:

The layout of a diesel engine power plant is shown in above figure.

- Diesel engine units are installed side by side with some room left fur extension in the future
- The repairs and usual maintenance works require some space around the units.
- The air intakes and filters are exhaust mufflers are located outside.
- Adequate space for oil storage, repair shop and office are provided as shown.
- Bulk storage of Oil may be outdoors.

Starting of engine:-

Following are the three common method of starting an engine.

i. By an auxiliary engine,

through a clutch and gears.

ii. By using an electric motor,

to an electric motor that derives the engine.

iii. By compressed air system,

is admitted to a few engine cylinders making them wo

engine shaft. Fuel is admitted to the remaining cylinders and ignited in the normal way causing

the engine to start. The compressed air system is commonly used for starting large diesel engines employed for stati

Essential component or element of diesel electric plant

1. Engine
2. Air intake system
3. Exhaust system
4. Fuel system
5. Cooling system
6. Lubrication system

1. Engine:-
It is the main component of the plant and is directly coupled to the

2. Air intake system:-

It conveys fresh air through louvers and air filter that removes dirt, etc. causing wear of the engine. Supercharger, if fitted, is generally driven by the engine itself and it augments the power
output of the engine.this is mounted close to the main engine and drives the latterin which a storage battery 12 to 36 volts is used to supply powerin which compressed air at about 17bar supplied from an air tankwork like reciprocating air motors to run thestationary power plant service.

3. Exhaust system:-
• Exhaust system discharge the engine exhaust to the atmosphere.
• The exhaust manifold connects the engine cylinder exhaust outlets to the exhaust pipe which is
provided with a muffler or silencer to reduce pressure on the exhaust line and eliminates most of the noise which may result if gases are discharged directly to
• The exhaust pipe should have flexible tubing system to take up the effects of expansion due to
high temperature and also isolate the exhaust system from the engine vibration.
There is scope of waste heat utilization from the diesel engin
i. By installing a waste heat boiler to raise low pressure steam which can be used for any process,
purpose or for generating electricity.
ii. The hot exhaust may also be utilized to heat water in a gas
in the form of a water coil installed in the exhaust muffler.
iii. It can also be used for air heating where the exhaust pipe is surrounded by the cold air jacket.
4. Fuel system:-
• Fuel oil may be delivered at the plant site by trucks, railway wagons or barges and oil tankers.
• An unloading facility delivers oil to the main storage tanks from where oil is pumped to small
service storage tanks known as engine day tanks, which store of operation.
• The fuel injection system is the heart of a diesel engine.
• Engines driving electric generators have lower speeds and simple combustion chambers that
promote good mixing of fuel and air.
5. Cooling system:-
The temperature of the gases inside the cylinder may be as high as 2750"C. If there is no external cooling, the cylinder walls and piston will tend to assume the average temperature of the
gases which may be of the order of 1000° to I500°C. The cooling of thefollowing reasons.

a) The lubricating oil used determines the maximum engine temperature that can be used. Above
these temperatures the lubricating oil deteriorates very rapidly and may evaporate and bum

damaging the piston and cy

b) The strength of the materials used for various engine parts decreases with increase in temperature.

c) High engine temperatures may result in very hot exhaust valve, giving rise to pre detonation or knocking.

d) Due to high cylinder head temperature, the volumetric efficiency and hence power outputs of
the engine are reduced. Theatmosphere. Engineexhaust, gas-to-water heat exchanger which can be oil for approximately eight hoursengine is necessary for thecylinder surfaces.

Following are the two methods of cooling the engine.

(i) Air cooling:
Air cooling is used in small engines, where fins are provided to increase heat transfer surf area.
(ii) Water cooling:
Big diesel engines are always water cooled. The cylinder and its head are enclosed in a water jacket which is connected to a radiator. Water flowing in the jacket carries away the heat from the
engine and becomes heated. The hot wa
heat to air from the radiator walls. Cooled water is again circulated in the water jacket. Various methods used for circulating the water around the cylinder are the following.

(a) Thermosiphon cooling: In this method water flow is caused by density difference. The rate of'
circulation is slow and insufficient.

(b) Forced cooling by pump: In this method a pump, taking power from the engine, forces water to
circulate, ensuring engine cooling under all operating conditions. There may be overcooling which may cause low temperature corrosion of metal parts due to the presence of acids.

(c) Thermostat cooling: This is a method in which a thermostat maintains the desired temperature
and protects the engine from getting overcooled.water then flows into the radiator and gets cooled by rejecting
(d) Pressurized water cooling:
increase heal transfer in the radiator. A pressure relief valve is provided against any pressure drop
or vacuum.
(e) Evaporative cooling: In this method water is allowed to evaporate absorbing the latent heal of
evaporation from the cylinder walls. The cooling circuit is such and the steam flashes in a separate vessel.

4. Lubrication system:-

• Lubrication is the flow of oil between two surfaces having relative motion.
• Following are the function of lubricating system.
(a) ***Lubrication:*** To keep moving parts sliding freely past each other, thus reducing engine friction
and wear.
(b) ***Cooling:*** To keep the surface cool by taking away a part of heat caused by friction.
(c) ***Cleaning:*** To keep bearing and friction ring clean of the product of wear and combustion by
washing them away.
(d) ***Sealing:*** To form a good seal between the piston ring and cylinder wall.
(e) ***Reduce noise:*** To reduce noise of engine by absorbing vibration.
Lubrication system can be classified as,
lubrication system and (c) Dry sump lubrication system.

(a) Mist lubrication system
This system is used for two stroke cycle engine which employs crankcase
compression. Thus crankcase lubrica

(b) Wet sump lubrication system
The bottom part of the crankcase, called sump, contains the lubricating oil which is pumped to the various part of the engine. There are three types of wet sump lubrication system; they are
Splash system, Modified splash system and Full pressure system
In this method a higher water pressure, 1.5 to 2bar, is maintained to that the coolant is always liquid

(a) Mist lubrication system, (b) Wet sump

Splash system:-
It is used for small four stroke stationary engines. The oil level in the sump is maintained in such a way that when the connecting rod's big end at its lowest position the dippers at the end strike
the oil in the troughs which are supplied with oil from the sump by an oil pump. Due to striking of
dippers oil splashes over various parts of engine like crank pin, bearing, piston ring, piston pin etc.
Excess oil drips back into the sump.
Modified splash system:-
The splash system is not sufficient if the bearing loads are high. For such cases, the modified splash system is used, where the main and camshaft bearings are lubricated by oil under pressure
pumped by an oil pump. The other engine parts are lubricated by
figure.

An oil pump is used to lubricate all the parts of the engine. Oil is pumped to the main bearing of the crankshaft and camshaft at pressure between 1.5bar to 4bar. Drilled
lubricate connecting rod end bearing.
A gear pump submerged in oil and driven by the camshaft draws the oil from the sump

through a strainer. A pressure relief valve is provided on delivery side to prevent excessive pressure.

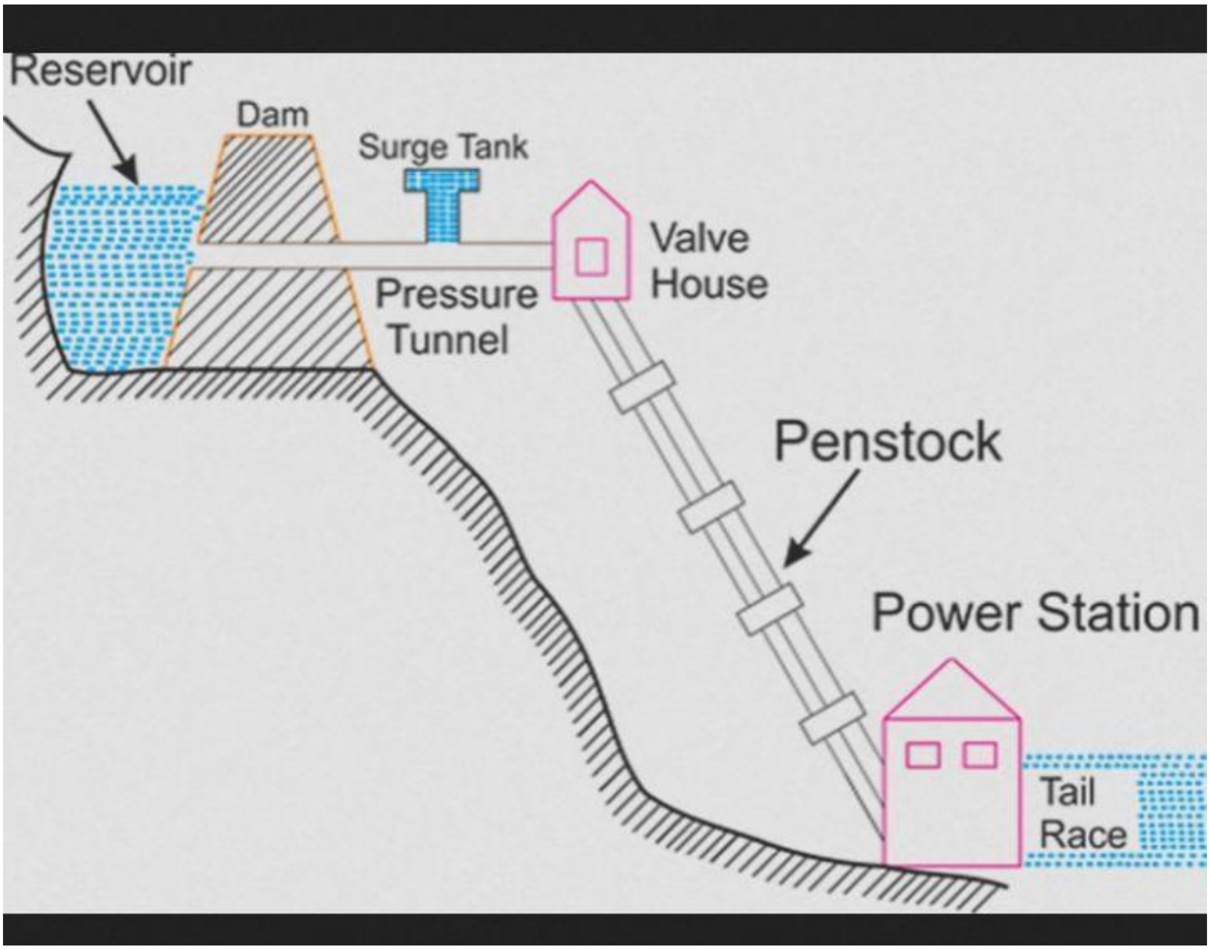
(c) Dry sump lubrication system

Oil from the sump is carried to a separate storage tank or supply tank outside the engine cylinder. The oil from the dry sump pumped through the filter to the storage tank. Oil from the supply
tank is pumped to the engine cylinder t
sump system is generally used for high capacity engine.
From the pump all the oil used for lubrication usually passes through an oil filter before itreaches engine bearing. The bearings are damaged if any foreign material is allowed to the lubrication line.

CHAPTER.5
HYDEL POWER PLANT:

General layout of Hydel power plant

FIG:



The main components of a storage type hydel power plant are as follows:
1. Catchment area
2. Reservoir
3. Dam
4. Penstock
5. Forebay
6. Power house
7. Draft tube
8. Spill way
9. Surge tank

1. Catchment Area:
• The complete area around the reservoir, around the river and the river basins near the reservoir is
termed the catchment area. A larger catchment area results in better run-off into the reservoir.
• The reservoir capacity and the dam size are dependent on the size of the catchment area.
2. Reservoir:
• The main purpose of reservoir is to store water during rainy season and supply the same during
dry season.
• The reservoir is located at a region of heavy rain fall; with sufficient catchment is intensity of the
rainfall.
3. Dam:
• The function of a dam is to increase the height of water level behind it, hence to increase the reservoir capacity.
• The dam also helps to increase the working head of the power plant.
4. Penstock:
• A pipe between the surge tank and prime mover is known as penstock.
• The structural design of a penstock is same as other pipes, except for that it is made stronger inside, to withstand high pressures caused by water hammer during load fluctuations.
• Penstocks are usually made of steel through.
• Penstocks are equipped with head gates at the inlet which can be closed during repair of the penstocks.
• In very cold weather conditions, it is better to bury the penstock to prevent the ice formation in the pipe and to reduce to number of expansion joints required.

5. For eBay:
• It serves as a regulating reservoir and temporary storage pond.
• It receives the excess water when the load on the plant is reduced and provides water for initial increment of an increasing load, while the water in the canal is being accelerated.
• Thus, fore bay is a naturally provided storage which is able to absorb the flow variations.
• This can also be considered as the naturally provided surge tank as it performs the work of a surge tank.

6. Power house:

- A power house should have suitable structure
- Its layout should be such that there is adequate space is provided for convenient dismantling and repair.
- Some of equipment power house are turbines, pumps etc.

7. Draft tube:

- This essential part of reaction turbine installation.
- It supplements the action of the runner by utilizing most of the remaining kinetic energy of the water at the discharged end of the runner.

8. Spill way:

- It is a safety device constructed with the dam. It functions when the dam faces flood problems.
- It allows the passage of excess water from the reservoir, whenever the level rises above the predetermined safer level, thus avoiding the damage to the dam.

9. Surge Tank:

- A Surge tank is a small reservoir in which water level rises or falls to swing so that they are not transmitted to penstock.
- It is not required if the power house is at a short distance from reservoir such as in low head plants but it is required for high head turbines.
- It is a protective device connected to
- It’s function is to protect penstock against water hammer effects during low demand periods and avoid vacuum effect during high demand periods.
- It achieves this by stabilizing the velocity and pressure in the penstock.the penstock.

CLASSIFICATION OF HYDEL PLANTS

1. According to Head of water,

a) Low head plant
b) Medium head plant
c) High head plant

2. According to Nature of

a) Base load plant
b) Peak load plant

3. According to Capacity

a) Low capacity plant (100
b) Medium capacity plant (1 MW
c) High capacity plant (above 10 MW)

4. According to Quantity of water

a) Run-off river plants without pondage
b) Run-off river plants with pondage
c) Pumped storage

1. According to Head of water,

a) Low head hydel power plant

• A hydel plant with a water head of less than 50 meters is termed a low head plant.
• In such plants, a small dam is constructed across a river to obtain the necessary water head.
• The excess water is allowed to flow over the dam, while the water head is made use to run a hydraulic turbine.
• Francis or Kaplan turbine is used to generate power.

b) Medium head hydel power plant:

• A hydel plant with a water head of in the range of 30 to 1
plant.
• In this, the water is stored in a main reservoir.
• This water is allowed to a small pond or forebay through a canal
• The water from the forebay is taken to the turbine through penstock.
• In such plants the forebay during the low demand periods.
• Francis turbine is most suitable for medium head hydel plants.

c) High head hydel power plant

• A hydel plant with a water head of more than 100 meters is termed a high head plant.
• In this case, the water from the main reservoir is carried through tunnels up to the surge tank, from where it is taken through the penstock.
• Since the water head is very
• Thus, it is essential to provide a surge tank in the water line at appropriate location.
• The surge tank takes care of the increasing and decreasing water levels during the low demand and high demand periods, respectively.
• The Francis and Pelton wheel turbines are most suitable for high head plants.

2. According to Nature of load

a) Base load plant:-

• *These plants are required to supply constant power in the grid.*
• *They run continuously without any interruption and are mostly remote controlled.*

b) Peak load plants:-

• *They only work during certain hours of a day when the load is more than the average.*
• *Thermal stations work with hydel plants in tandem to meet the bas*
*during various seasons.*100 meters is termed a medium headitself acts as the surge tank, and hence receives the excess water

4. According to Quantity of water

a) Run-of-river plant without pondage

• In such plants water is **not stored,**
• In such power plants the
• Hence, during rainy seasons some excess quantity of water may run waste without doing any
power generation.
• During dry periods the power production will be very poor, since the water flow
low.

b) Run-of-river plant with pondage

• In such plants, the excess water available during rainy seasons is stored in the reservoirs.
• The plant works with the normal run
the reservoir is utilised to supplement the low flow rate during dry periods.
• Power production will not be affected by the dry seasons.
• Hence, plants with pondage can generate a constant rate of power throughout the year.

c) Pumped storage plant:-

The schematic arrangement of pumped storage plant operating along with a thermal plant to meet the peak load demands, is shown in above figure
• Such plants are most suitable for supplying sudden peak load requirements.
• However, such demands can meet the average demand only.
• Such type of plant consists of two storage reservoirs.
• The upstream reservoir is the main storage reservoir to which water flows from the catchment area
• The second reservoir is the downstream (tail race) reservoir, in which the used water from the upstream is collected.
• The water in the downstream reservoir is pumped back to the main upstream reservoir, during off peak periods.
• This facilitates making use of the
• A pumped storage plant is a peak load plant arid operates in combination with other base load plants such as a thermal power plant.
• The off peak load capacity of the thermal plant is used for pumping water from the downstream reservoir to the main upstream reservoir.

Storage &Pondage

• Storage plants are the plants with facilities for storing water at their sites.
• However, often such plants cannot store as much water as required for the full year operation.
• For continuous operation, it is always preferred to have one or more reservoirs upstream.
• Depending upon the place of storage and the function, the reservoirs are grouped asstorage and pondage

Storage:-

• Storage can be defined as
seasons, which is essentially used in the dry seasons for the plant operation
• This is the main, or the upstream reservoir, made by the construction of a dam across the stream.

Pondage:-

• It is defined as **a regulating means of water, and is a small reservoir that is used for the collection of the excess flow water from the dam spill ways of the main reservoir or from/the river stream**.
• It is basically a small pond or reservoir just behind the power house.
• The amount of regulation obtained with pondage usually involves storing water during low loads (during low power demand periods such as early morning hours and Sundays) to aid carrying peak loads during the week.

• The water that would go over the dam spill
added to normal river flow to supply peak loads, usually for a few hours of duration
• For fluctuating loads, pondage increases the maximum capacity that a plant can carry.
• Plants with reservoirs upstream can s
summer to supplement the low rates of flow during this dry season
• Reservoir water elevation will generally be lowest during the year at the end of the summer.
• Pondage increases the capacity of a river for a brief period only, like for 8 week.
• But, storage increases the capacity of a river over an extended period such like 6 months to 2 years.

Hydrographs:-

• It is a **graph representing**period.
• The time axis may have units of hour, day, week or month.
• The discharge units may be
• Discharge hydrographs are also known as

Uses of a Hydrographs:

A hydro graph is useful to determine a number of parameters, such, as:
1) **Rate of flow** at any instant during the specific recorded period.
2) **Total volume** of flow in a given period, as the area under the hydrograph represents the volume of water in a given duration.
3) The mean annual run-off
4) The **maximum and minimum run**
5) The **maximum rate of run**

Gates and valves:

Drum Gate:-

m3/s/week or any other convenient unit of time.
possible to estimate the total power available at the
minimum and maximum
then the curve is known as
is known practically then power of plant, **P** can be obtained from
$P=\rho gHQ\eta_0$(in **W)**
ρ = 1000kgm-3 is density of water
g = 9.81ms-2 is acceleration due to gravity
H is height of water in m
Q is discharge in m3/s
$\eta_0$is overall efficiency

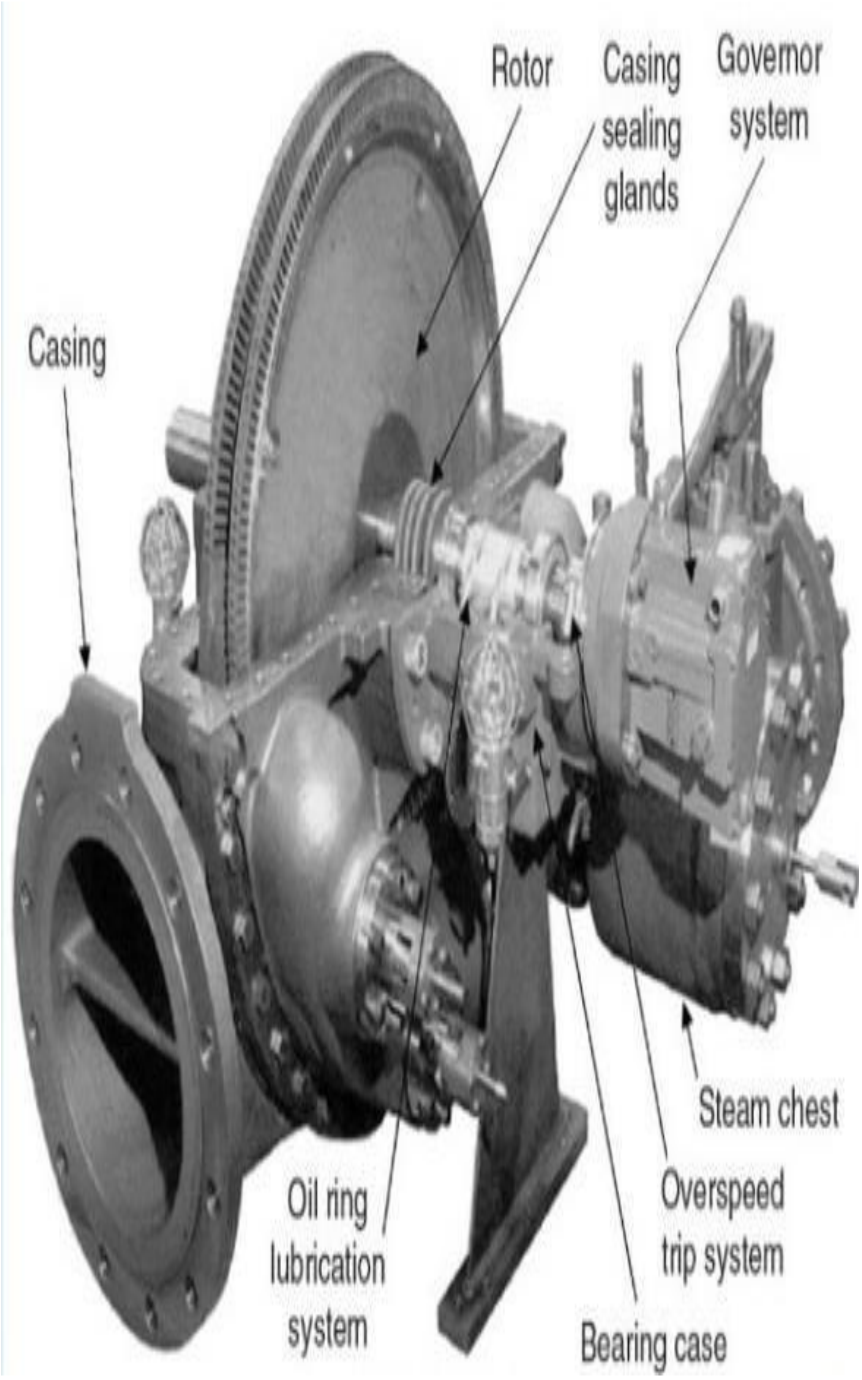
Needle valve:-

Brief description of Hydraulic installation in India

Hydro electric power was initiated in India in 1897 with a run off river unit near Dargiling. However, the first major plant was sivasamudram scheme in mysore of 4.5MW capacity commissioned in 1902 Kopholi project of 50MW in Maharastra was put into operati supply power to Bombay city. Since independence pressure.

Most of the turbine have casings with horizontal split type. Due to horizontal split it easy for assembling and dismantling for maintenance of turbine. Also, maintain proper axial and radial clearance between the rotor and stationary parts.

Usually, the turbine casings are heavy in order to withstand the high pressures and temperatures. It is general practice the thickness of walls and flanges decrease from the inlet to exhaust end due to the decrease in steam pressure from inlet to exhaust.



Turbine Casing MOC

Large casings for low-pressure turbines are of welded plate construction, while smaller L. P. casings are of cast iron, which may be used for temperatures up to 230°C.

Casings for intermediate pressures are generally of cast carbon steel able to withstand up to 425°C. The high-temperature high-pressure casings for temperatures exceeding 550°C are of cast alloy steel such as 3 Cr 1Mo (3% Chromium + 1% Molybdenum.) The turbine casings are subjected to maximum temperatures and under constant pressure. Hence the material of casing shall subject high "Creep". (Click *here* to read more about material properties)

The casing joints are made of steam tight by matching the flange faces very exactly and very smoothly, without the use of gaskets. Dowel pins are used to secure exact alignment of the casing flange joints.

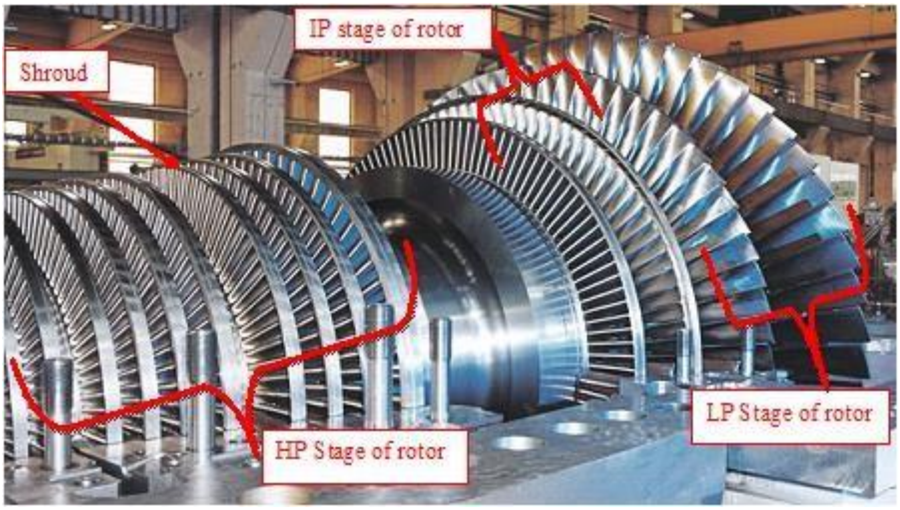
The casing contains grooves for fixing the diaphragms (for impulse turbines) or for the stationary blades (reaction turbines). (Click *here* to read more about impulse and reaction turbines

Turbine Rotors

The steam turbine rotors must be designed with the most care as it is mostly the highly stressed component in the turbine. The design of a turbine rotor depends on the operating principle of the turbine.

The **impulse turbine,** in which the pressure drops across the stationary blades. The stationary blades are mounted in the diaphragm and the moving blades fixed or forged on the rotor. Steam leakage is in between the stationary blades and the rotor. The leakage rate is controlled by labyrinth seals. This construction requires a disc rotor.

The **reaction turbine** has pressure drops across the moving as well as across the stationary blades. The disc rotor would create a large axial thrust across each disc. Hence disc rotors are not used in the reaction turbine. For this application, a drum rotor is used to eliminate the axial thrust caused by the discs, but not the axial thrust caused by the differential pressure across the moving blades. Due to this, the configuration of reaction turbine is more complicated.



Disc Type Rotors

This type of rotor is largely used in steam turbines. The disc type rotors are made by forging process. Normally the forged rotor weight is around 50% higher than the final machined rotors. Refer above figure for disc type rotor.

Drum Type Rotors

Initially, the reaction turbines rotors are made by solid forged drum-type rotor. The rotors are heavy and rigid construction. Due to this, the inertia of the rotor is very high when compare with the disc-type rotor of the same capacity. To overcome this nowadays the hollow drum-type rotors are used instead of solid rigid rotors. Usually, this type of rotor is made of two pieces construction. In some special cases, the rotor is made up of multi-piece construction.

The drums are machined both outside and inside to get perfect rotor balance.

Turbine Blades

The efficiency of the turbine depends on more than anything else on the design of the turbine blades. The impulse blades must be designed to convert the kinetic energy of the steam into mechanical energy. The same goes for the reaction blades, which furthermore must convert pressure energy to kinetic energy.

The blades are strong enough to withstand the following factors

- High temperatures and stresses due to the pulsating steam load
- Stress due to centrifugal force
- Erosion and corrosion resistance.

Depend upon the pressure region the blades are also classified as follow. Refer above figure for rotor pressure region

- High Pressure (HP) blades
- Intermediate Pressure (IP) blades
- Low Pressure (LP) blades

The turbine blades are made up of chromium-nickel steel or 17 Cr'13 Ni – steel.

Stationary Blades (Diaphragms) and Nozzles

Nozzle:

Nozzles are used to guide the steam to hit the moving blades and to convert the pressure energy into the kinetic energy. In the case of small impulse turbine, the nozzles are located in the lower half of the casing. But in the case of the larger turbine, the nozzles are located on the upper half of the casing.

Stationary Blades (Diaphragms)

All stages following the control stage have the nozzles located in diaphragms. The diaphragms are in halves and fitted into grooves in the casing. Anti-rotating pin or locking pieces in the upper part of the casing prevent the diaphragm to rotate.

All modern diaphragms are of an all-welded construction. The stationary blades in reaction turbines are fitted into grooves in the casing halves; keys as shown lock the blades in place. In some cases, the blades have keys or serration on one side of the root and a caulking strip on the other side of the root is used to tighten the blades solidly in the grooves.

Blade Fastening

After turbine blades are machined through the milling process. Then the blades are inserted in the rotor groove. Depend upon the application the blade root section varies

Blade roots are subject to take four types of stress

- Tensile stress due to the centrifugal forces
- Bending stress due to fluid forces act on the blade in tangential direction
- Stress due to vibration forces.
- Thermal stress also due to the uneven heating of the blade root and the rim.

Twisted Blades

This type of blades is used in the last stage of a large multistage steam turbine. These are the largest blade in turbine and contribute around 10% of the turbine total output. Due to larger in size, these types of blades are subjected to high centrifugal and bending forces. To overcome these forces twisted construction is used.

Shrouds

Shrouds are used to reinforce the turbine blades free ends to reduce vibration and leakage. This is done by reverting a flat end over the blades refer figure. In some cases especially at the early stages, the shroud may be integral with the blade. When the blades are very long as in the case of the last stage of LP turbine. The rotor blades are further reinforced by using lacing wires (caulking wire) which circumferentially connects all the blades at a desired radius and shrouding is eliminated.

Turbine Barring device

When a turbine is left cold and at standstill, the weight of the rotor will tend to bend the rotor slightly. If left at the standstill while the turbine is still hot, the lower half of the rotor will cool off faster than the upper half and the rotor will bend upwards “hog”. In both cases, the turbine would be difficult if not impossible to start up. To overcome the problem the manufacturer supplies the larger turbines with a turning or barring gear consisting of an electric motor which through several sets of reducing gears turns the turbine shaft at low speed.

The first turning gears turned the shaft at approximately 20 rev/mm, later increased to 40 and up to 60 rev/mm as proper lubrication is difficult to obtain at low speed; the same goes for the hydrogen seals of generators. Some turning gears, electric or hydraulic, turn the shaft 1 800 at set times over a period of 24 hours.

Before a cold turbine is started up it should be on the barring gear for approximately three hours. When a turbine is shut down, it should be barring for the next 24 hours. If a hydrogen-cooled generator is involved the turbine should be kept on barring gear to prevent excessive loss of hydrogen, All barring gears are interlocked with a lubricating oil pressure switch and an engagement limit switch operated by the engagement handle.

Turbine Bearings

One of the steam turbine basic part is bearing. They are two types of bearings used based on the type of load act on them

- Radial Bearing
- Thrust Bearing

Radial Bearings

For small turbines mostly equipped with anti-friction type bearings. Widely used anti-friction bearings are the self-aligning spherical ball or roller bearing with flooded type lubrication is used.

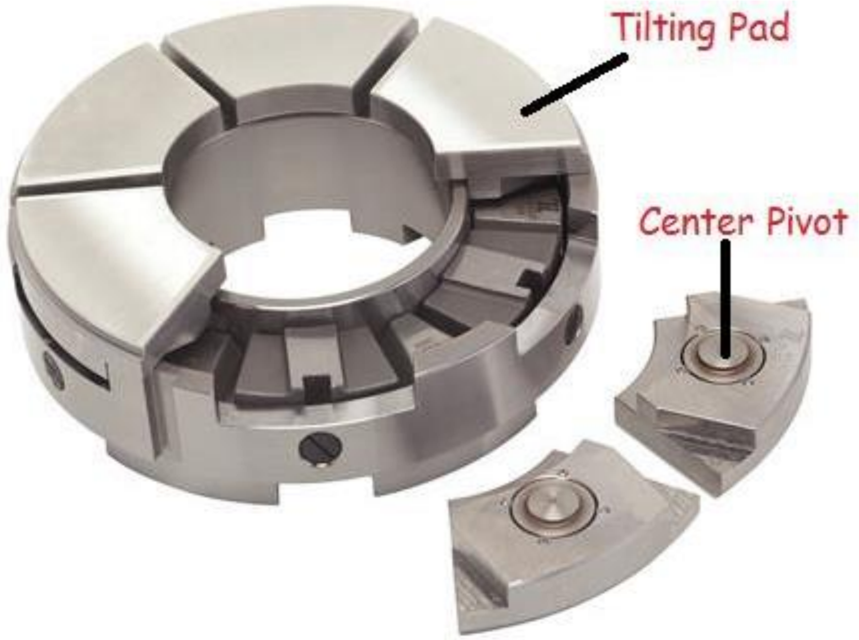
In the case of medium turbines used plain journal bearing. They may be ring lubricated sleeve bearings with bronze or Babbitt lining. Both flooded and force types are employed.

For larger turbines, the radial bearing will be a tilting pad type. The number of pad per bearing will be selected based on the weight of the rotor. For these types of bearing forced lubrication is used.

Thrust Bearings

The main two purposes of the thrust bearing are:

- To keep the rotor in an exact position in the casing.
- To absorb axial thrust on the rotor due to steam flow.



The thrust bearing is located on the free end of the rotor or we can say at the steam inlet of the turbine. The axial thrust force is very small for impulse turbines. This is due to the presence of pressure equalizing holes in the rotor discs to balance the thrust force generated across the disc. A simple thrust bearing such as a ball bearing for small turbines and radial babbitt facing on journal bearings are commonly used in small and medium-size turbines. Tilling pad type thrust bearings are used in the large steam turbines.

In the case of reaction turbine, the pressure drop across the moving blades creates a heavy axial thrust force in the direction of steam flow through the turbine. Due to greater thrust force, the heavy duty thrust bearing such as tilting pad type thrust bearings are used. The axial thrust in reaction turbines can be nearly reduced by the using off balance or dummy pistons.

As we seen the purpose, the thrust bearing not only taking the thrust load and also to maintain the position of the rotor. The axial position of the rotor is very important and an axial position indicator is often applied to the thrust bearing. As a normal practice, the axial position of rotor exceeds 0.3 mm alarm and shutdown at 0.6 mm. (Readers please note these valves are thumb rule, it may change with respect to manufacturer and turbine model)

Turbine Seals

Seals are used to reduce the leakage of steam between the rotary and stationary parts of the steam turbine. Depend upon the location of seal, the seals are classified as two types, they are

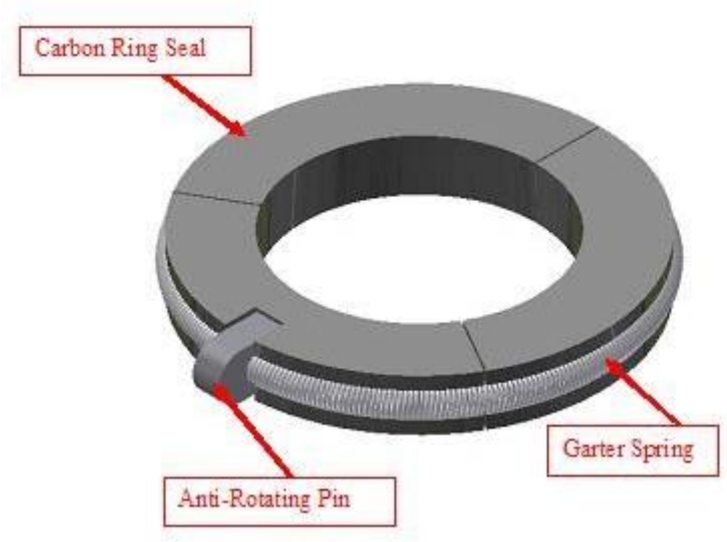
- Shaft Seal
- Blade Seal

Shaft Seals

Shaft seals are used to prevent the steam leakage where the shafts extend through the casing. In the case of a small turbine (as per API 611) carbon rings are used as shaft seal up to the surface speed of the shaft is 50m/s. The carbon ring is made up of three segments butting together tightly under the pressure of a garter spring. The carbon rings are free floating in the housing and an anti-rotating pin is used to prevent the rotation of carbon ring seal.

Due to the self-lubrication properties of the carbon rings, they maintain a close clearance with the shaft. Refer below figure.

For larger steam turbines (as per API 612) labyrinth seal are used as shaft seals. In the case of condensing steam turbine to prevent the air ingression at the shaft seal by Gland condenser and ejector arrangements(as per API 612).



Blade Seals

Blade seals are used to prevent the steam leakage between the diaphragm and the shaft. The efficiency of the turbine depends largely on the blade seals. Labyrinth seals are used as blade seals in the small and large turbines. In the case of large steam turbine spring loaded labyrinth seals are used.

The seals are made up of brass or stainless steel. Also, the sharp edge gives better sealing and rubs off easily without excessive heating in case of a slightly eccentric shaft. Some labyrinth seals are very simple, others are complicated.

Turbine Couplings

The purpose of couplings is to transmit power from the prime mover to the driven piece of machinery. Flexible type couplings are used in turbines. The coupling hubs are taper bore and key way to fit the tapered end of the shaft.

Governor

The governor is one of the steam turbine basic parts. Its main function is to control the operation of a steam turbine. Generally, the governor is classified as two type

- Speed-sensing governor
- Pressure sensing or load governor

Speed Sensing Governor

Speed-sensing governors are used in power generation application to maintain a constant speed with respect to the load change in governor. Droop is one of the important characteristics of this governor selection.

Pressure sensitive governor

These are applied to back pressure and extraction turbines in connection with the speed sensitive governor.

They are three types of governor used in steam turbine

- Mechanical Governor
- Hydro-mechanical Governor
- Electronic Governor

In the case of small turbine Oil relay type (Hydro-mechanical) governor NEMA class “A” is used. For the larger turbine, electronic governor NEMA class “D” is used.

Lubrication System

Oil flood lubrication is used for small turbines and pressurized lubrication is used for larger turbines. The pressurized lubrication system consists of lube oil tank, oil pump, filter, cooler, pressure regulating valve, etc., The pressurized lubrication system of turbine shall be as per API 614.