UNIT I

COAL BASED THERMAL POWER PLANTS

INTRODUCTION TO THERMAL POWER PLANTS :-

Steam is an important medium for producing Mechanical energy. A steam power plant continuously converts the energy stored in fossil fuels (coal, oil and natural gas) in the form of heat energy. Steam has the advantage that it can be raised from water which is available in abundance. The steam power stations are very much suitable where the coal is abundantly available. The pressure ranges from 10 kg/cm^2 to super critical pressure and the temperature varies from 250°C to 650°C

Thermal plants are not suitable for supplying fluctuating loads because any change in the load demand requires the corresponding change in output energy. In thermal power plants, the input energy is produced by burning the coal. So, there is always a large time lapse between the change in energy output and input which is not desirable. Therefore, such power stations are used only as base load stations and it supplies constant power.

factors to decide the unit size of power plants :-

(i) Required amount of power
(ii) Cost
(iii) Availability of resources
(iv) Technological aspects.

Sources of Energy Available for power Generation :-

1. steam
2. Gas or air
3. Diesel and petrol
4. Nuclear
5. Renewable energy sources such as solar, wind, geothermal, tidal, wave, MHD etc.

RANKINE CYCLE :-

Rankine cycle is the theoretical cycle on which the steam turbine works. Rankine cycle is an ideal cycle for vapour power cycles. The line diagram of the plant working on the cycle is shown as. Rankine cycle has the following processes.

Processes :-

1-2 => Reversible adiabatic expansion in the turbine

2-3 => Constant pressure heat transfer in the Condenser.

3-4 => Reversible adiabatic pumping process in the feed pump.

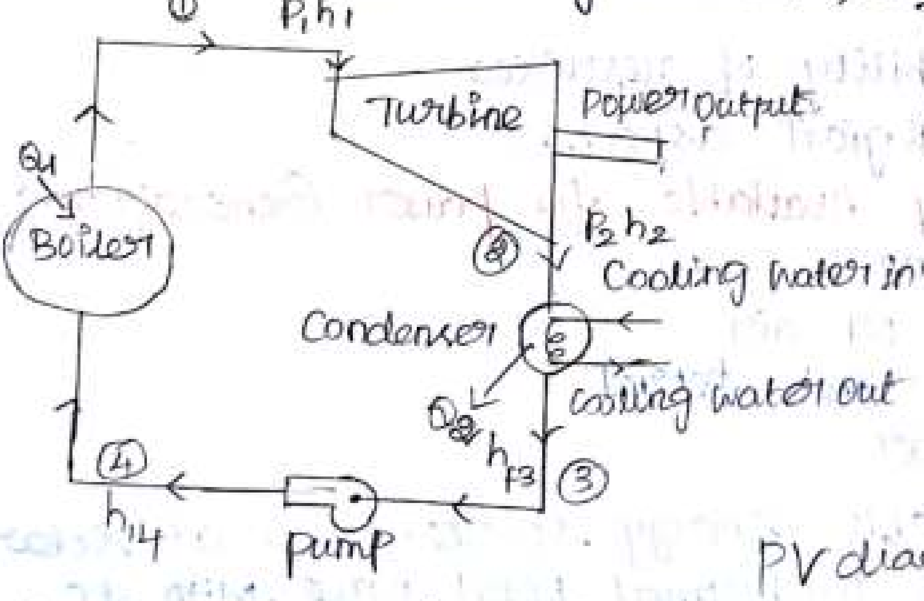
4-1 => Constant pressure heat transfer in the boiler.

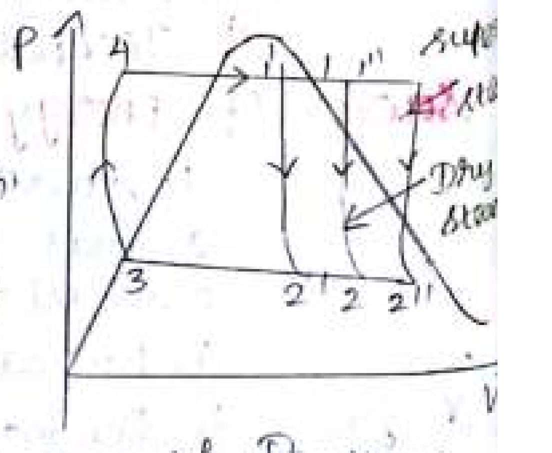
To analyse the cycle, 1 kg of fluid is taken and the steady flow energy equation is applied to boiler, turbine, condenser and pump.

Process 1-2 (Turbine)

The dry saturated steam from boiler (point 1) is isentropically expanded in the turbine (up to point 2) for developing mechanical work and hence, the pressure of steam falls from P_1 to P_2. The temperature at the end of expansion is T_2 which is the saturated temperature at condenser pressure P_2. The steam after expansion is in wet condition with dryness fraction x_2

Work done by turbine, $W_T = h_1 - h_2$





PV diagram of Rankine cycle

process 2-3 (Condenser) :-

The wet steam is then condensed in a condenser isothermally and isobarically. The wet steam is converted into water in the condenser. This process is a heat rejection process but the heat is rejected from wet steam to atmosphere..

Heat rejected in the condenser $Q_R = h_2 - h_3 = h_2 - h_{f_2}$

(ie) $h_3 = h_{f_2}$

process 3-4 (pump) :-

The water from the condenser is isentropically pumped from pressure P_3 to the boiler pressure P_4. There is a slight rise in temperature from T_3 to T_4. The enthalpy of water increases due to the pump work.

work done by pump, $W_p = h_4 - h_3 = v_3 (P_4 - P_3)$

$$W_p = v_{f_3} (P_4 - P_3) = v_{f_2} (P_1 - P_2)$$

(ie) $P_4 = P_1$; $P_3 = P_2$; $v_3 = v_{f_2}$

process 4-1 (Boiler) :-

The heat is supplied by the boiler to raise the temperature of water to saturated temperature of T_5 at pressure of P_5.

Heat supplied during 4-1

$$Q_{S_{4-1}} = h_1 - h_4$$

heated
n

$$Q_S = h_1 - h_4 = h_1 - h_{f_4} \quad \therefore h_4 = h_{f_4}$$

$$Q_S = h_1 - (h_3 + W_p)$$

$[\because h_4 = h_3 + W_p = h_{f_2} + W_p]$

Net work output, $W = W_T - W_p$

$$= (h_1 - h_2) - W_p$$

$$= h_1 - (h_{f_2} + W_p)$$

Efficiency of the cycle $\eta = \frac{W}{Q_S}$

$$= \frac{(h_1-h_2)-W_p}{h_1-(h_{f_2}+W_p)}$$

Otherwise, $\eta = \frac{Q_S - Q_R}{Q_S}$

$$= \frac{(h_1-h_4)-(h_2-h_3)}{h_1-h_4} = \frac{(h_1-h_2)-(h_4-h_3)}{h_1-h_4}$$

$$\eta = \frac{(h_1-h_2)-W_p}{h_1-(h_{f_2}+W_p)}$$

The pump work is too small when compared to expansion work. Hence, it may be neglected for the low-pressure operation. But, it should be included for high-pressure operation.

If the pump work is neglected, then the efficiency equation is reduced to

$$\eta = \frac{h_1-h_2}{h_1-h_3} = \frac{h_1-h_2}{h_1-h_{f_2}} \quad (h_3 = h_{f_2})$$

T-s diagram for Rankine cycle without feed pump

TS diagram

(i) Specific steam consumption (SSC) :-

It is defined as the mass flow of steam required to develop 1 unit of power output.

$$SSC = \frac{3600}{W} \text{ in kg/kh.}$$

Where W be the network output

$W = (h_1-h_2)-W_p$ → for cycle with pump work

$W = h_1-h_2$ → without pump work

$W = h_1-h_2$ → without pump work

(ii) Specific steam flow rate (SSF) :-

It is defined as the steam flow in kg required to develop 1 unit of power output

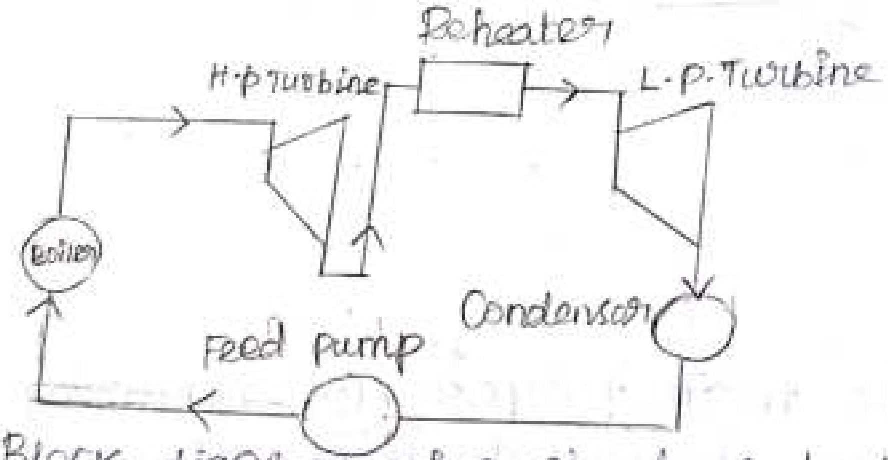
$$SSF = \frac{3600}{W} \text{ in kg/kWh}$$

(iii) Work ratio :
It is defined as the ratio of network to the gross work

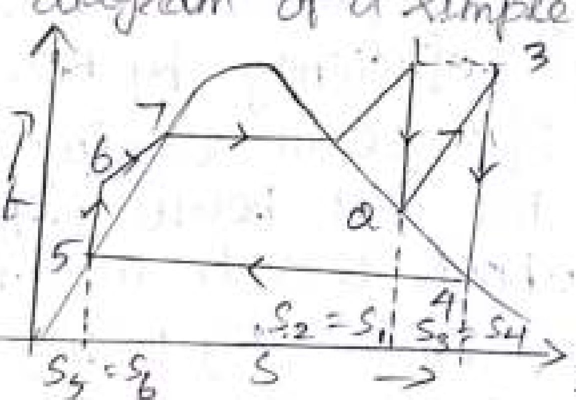
$$\text{Work ratio} = \frac{\text{Net work}}{\text{Gross work}} = \frac{W_T - W_P}{W_T}$$

IMPROVISATIONS OF RANKINE CYCLE :-
Rankine can be improved in three ways such as
(i) Reheating
(ii) Regeneration
(iii) Combined reheating and regeneration.

Reheat Rankine cycle :-
It is desirable to increase the average temperature and pressure of steam at which the heat is supplied and also to keep the steam as dry as possible at the end of turbine. If the pressure increases, the expansion ratio in the turbine will also increase and the steam becomes wet at the end of expansion. Increasing the moisture of steam will cause the erosion of turbine blades and increase in turbine losses.



Block diagram of a simple reheat Rankine cycle



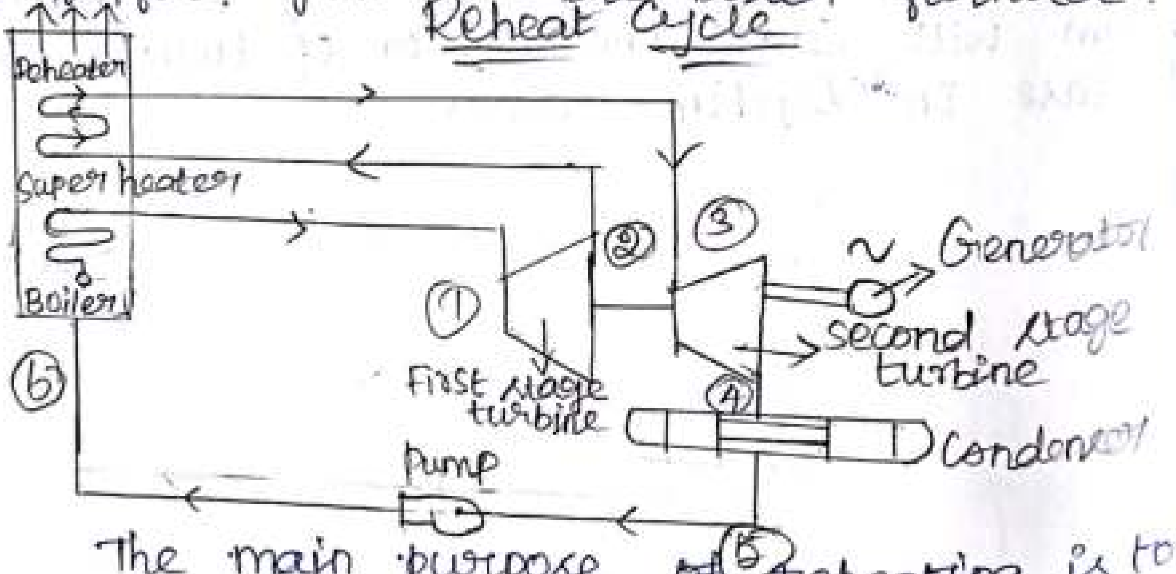
Reheat Rankine cycle

In the reheat cycle, the expansion is being carried out in two stages. The steam is initially expanded in H.P. turbine to some

help of [illegible] expanded in L.P [illegible]
steam is expanded in L.P turbine to the condenser pressure. The main purpose of reheating is to increase the dryness fraction of the steam passing through the turbine and it should never fall below 0.88. The thermal efficiency is increased with the reheat cycle but the specific steam consumption is reduced. But, the thermal efficiency of the reheat cycle may be decreased if it is used at low pressures. T-S diagram for reheat cycle :

The efficiency of the ordinary Rankin cycle can be improved by increasing the pressure and temperature of steam entering into the turbine. In the reheat cycle, the steam is extracted from a suitable point in the turbine and it is reheated with the help of flue gases in the boiler furnace.

Reheat Cycle



The main purpose of reheating is to increase the dryness fraction of steam and improve the cycle efficiency by 5%. but the dryness fraction of steam coming out of turbine should not fall below 0.92. The cost of reheat cycle is about 5% to 10% more than a simple Rankine cycle. By using the reheat cycle, the specific steam consumption decreases and thermal efficiency increases. Normally, the reheat pressure is [illegible] of the

Initial pressure of the steam.

The process 1-2 represents the Isentropic expansion in high pressure turbine and 3-4 represents the Isentropic expansion in low pressure turbine. The steam is reheated at constant pressure process 2-3. The reheat can be carried out by returning the steam to the boiler and passing it through a heat exchanger placed in the boiler at constant pressure. Other processes are similar to a simple Rankine cycle

$$\text{Heat supplied } Q_s = Q_{s_{1-6}} - Q_{s_{2-3}}$$
$$= (h_1 - h_6) + (h_3 - h_2)$$

$$\text{Work output, } W = (W_{1-2} + W_{3-4} - W_p)$$
$$= (h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)$$

Therefore, the efficiency of the reheat Rankine cycle is

$$\eta_{reheat} = \frac{(h_1 - h_2) + (h_3 - h_4) - W_p}{h_1 - (h_{f_4} - W_p) + (h_3 - h_2)}$$

where $W_p = v_{f4}(P_1 - P_4)$

If the pump work is neglected

$$\eta_{reheat} = \frac{(h_1 - h_2) + (h_3 - h_4)}{(h_1 - h_{f_4}) + (h_3 - h_2)}$$

Where $h_1 \Rightarrow$ enthalpy of super heated steam
$= h_{g_1} + C_{pg}(T_{sup} - T_{sat})$

$h_2 \Rightarrow$ enthalpy of steam at intermediate pressure P_2

If $s_2 = s_1$, the steam is in dry condition, then $h_2 = h_{g_2}$

If $s_2 < s_1$, the steam is in super heated condition, then
$h_2 = h_{g_2} + C_{pg}(T_{sup} - T_{sat})$

$s_2 > s_1$, the steam is in wet condition $h_2 = h_{f_2} + x_2 h_{fg_2}$

$h_3 \Rightarrow$ Enthalpy of super heated steam at pressure $P_3 = P_2$

$h_4 \Rightarrow$ Enthalpy of steam at pressure P_4
(ie) Condenser pressure

h_6 => Enthalpy of steam at pump ...

$h_6 = h_5 + W_p$

$W_p = (P_6 - P_5) \times v_5$

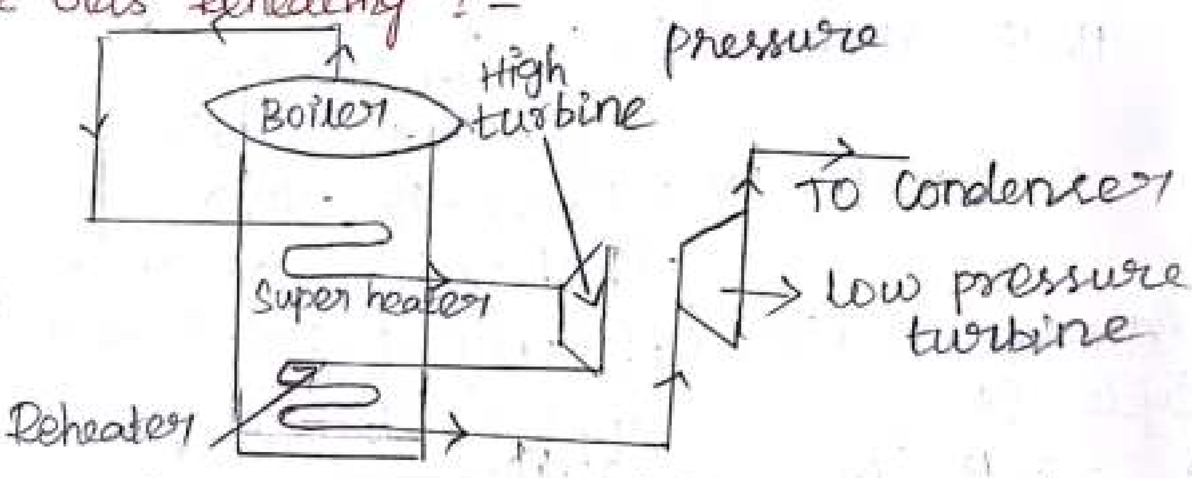
$W_p = (P_1 - P_4) \times v_{f4}$ $[\because P6 = P_1 \quad P_5 = P_4]$

$v_5 = v_f$ at condenser pressure.

Types of reheating :-

1. flue gas reheating
2. Live steam reheating
3. Combined flue gas and live steam reheating

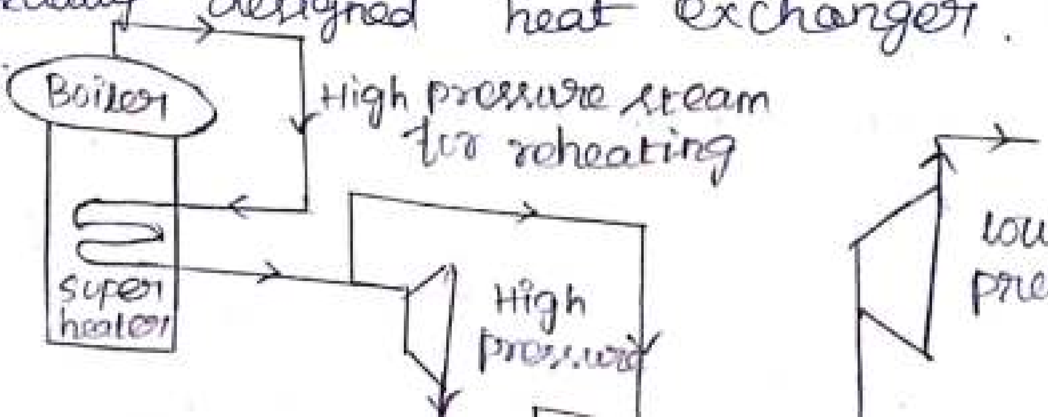
flue Gas Reheating :-



In this method, the flue gas coming out from boiler is used to heat the steam. The reheater is always placed behind the high-pressure super-heater. The steam can be reheated to initial throttle temperature as reheating is normally employed by using a counter flow heat exchanger.

Live-steam Reheating :-

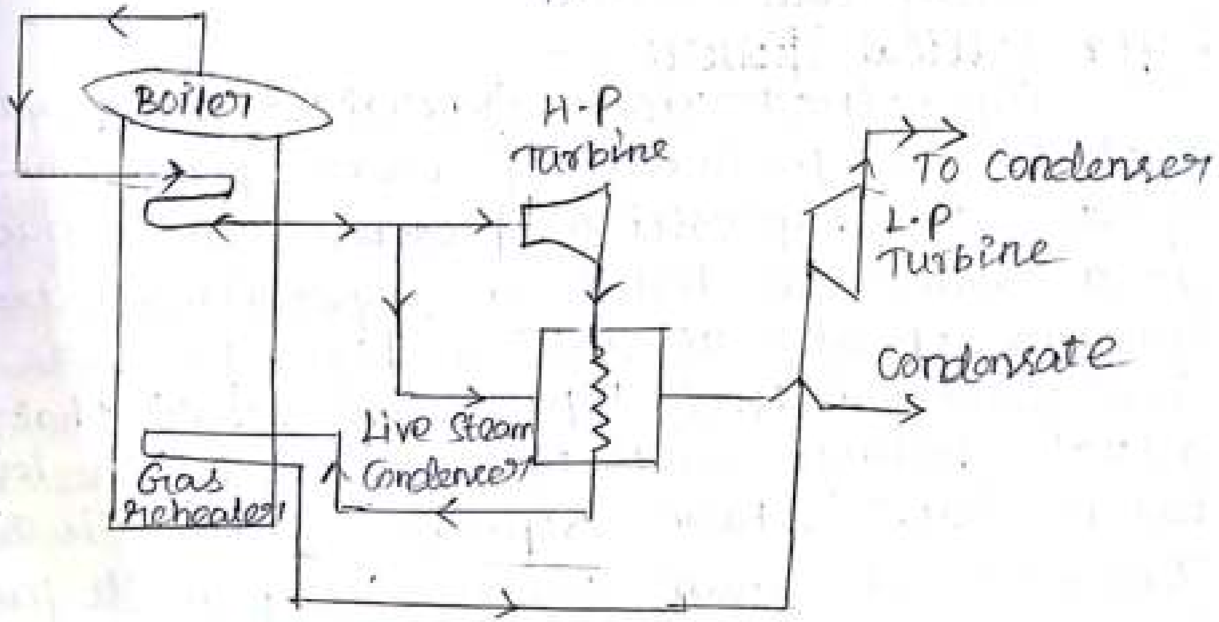
In this process, the high-pressure steam from the boiler is used for reheating the steam coming out from H.P turbine in a specially designed heat exchanger.



The main advantages in this process are as follows
1. The reheater can be placed near the turbine Therefore, it avoids the use of large piping.
2. It is simple in operation.

Combined Gas and Live steam Reheating :-

In the combined heating system it limits the steam reheated to its initial throttle temperature and the live steam reheating is eliminated. The steam coming out from H.P turbine is first passed through the live steam reheated and then it goes to a gas reheated. After reheating the steam in the gas reheated the steam is put through the low-pressure turbine. Initially, the steam from the boiler is superheated in the super heater.



THERMAL POWER PLANT :-

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle. The greatest variation in the design of thermal power stations is due to the different fuel sources. Some prefer to use the term energy center bec. such facilities convert forms of heat energy into electricity. Some thermal power plants also deliver heat energy for industrial purpo for district heating or for desalination of water as well as delivering electrical power. Large proportion of CO_2 is produced by the hot fossil fired thermal power plants; Efforts to reduce these outputs are various and widesp.

The four main circuits one would come across in any thermal power plant layout are

- Coal and Ash circuit
- Air and Gas circuit
- feed water and steam circuit
- cooling water circuit

Super critical Boilers :-

Supercritical steam generators are freq. used for the production of electric power. The operate at "supercritical pressure". In contrast to a "subcritical boiler" a supercritical ste. generator operates at such a high pressure (over 3,200 psi/22.06 Mpa or 220.6 bar) that actual boiling ceases to occur, and the b. has no water-steam separation. There is generation of steam bubbles can form. It pa below the critical point as it does work in the high pressure turbine and enters the generator's condenser. This is more efficient resulting in slightly less fuel use. The ter. "boiler" should not be used for a super critical pressure steam generator, as no "boiling" actually occurs in this device

FLUIDIZED BED BOILERS :-

The major portion of the coal availabl

low calorific value. The traditional grate fuel firing systems have got limitations and are techno-economically unviable to meet the challenges of future. Fluidized bed combustion has emerged as a viable alternative and has significant advantages over conventional firing system and offers multiple benefits - compact boiler design, fuel flexibility, higher combustion efficiency and reduced emission of noxious pollutants such as SOx and NOx. The fuels burnt in these boilers include coal, washery rejects, rice husk, bagasse & other agricultural wastes. The fluidized bed boilers have a wide capacity range - 0.5 T/hr to over 100 T/hr

SURFACE CONDENSER :-

Surface condenser is the commonly used term for a water-cooled shell and tube heat exchanger installed on the exhaust steam from a steam turbine in thermal power stations. These condensers are heat exchangers which convert steam from its gaseous to its liquid state at a pressure below atmospheric pressure. Where cooling water is in short supply, an air-cooled condenser is often used. An air-cooled water condenser is however significantly more expensive and cannot achieve as low a steam turbine exhaust pressure as a water cooled surface condenser.

Surface condensers are also used in applications and industries other than the condensing of steam turbine exhaust in power plants.

In thermal power plants, the primary purpose of a surface condenser is to condense the exhaust steam from a steam turbine to obtain maximum efficiency and also to convert the turbine exhaust steam into pure water (referred to as steam condensate), so that it may be reused in the steam generator or boiler as boiler feed water.

STEAM TURBINE

The steam turbine itself is a device convert the heat in steam to mechanical p. The difference between the heat of steam per unit weight at the inlet to the turbine a the heat of steam per unit weight at the outlet to the turbine represents the heat which is converted to mechanical power. There the more the conversion of heat per pound kilogram of steam to mechanical power in turbine, the better is its efficiency. By cond. the exhaust steam of a turbine at a pressure below atmospheric pressure, the ste pressure drop between the inlet and exhaus of the turbine is increased, which increases the amount of heat available for conver. to mechanical power. Most of the heat libe due to condensation of the exhaust steam is carried away by the cooling medium used by the surface condenser.

fuel and ash handling :-

Ash Handling systems is the none/un combusted portion or residue, after taking combustion of any solid fuel is usually coal. And any coal contains some non combustible portion which is called ash. Content of that coal.

There are different types of ashes :

- Bottom ash
- fly ash

Bottom ash is the residue which remains in the solid from at the bottom and fly ash is the light particle which goes out al with exhaust gases and usually they are collected in chimneys.

Taking their so formed ash away from the plant / Boiler is called - "ASH HANDLING SYSTEM"

This is done in either.

- Mechanical conveying
- Pneumatic conveying

DRAUGHT SYSTEMS :-

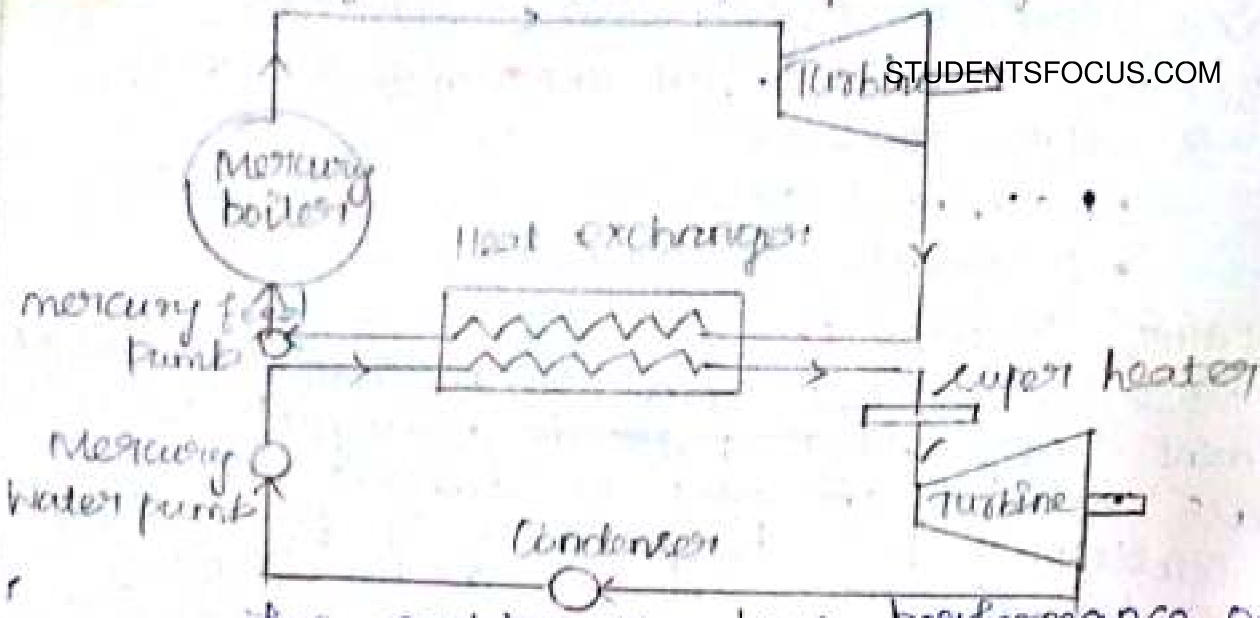
Most boilers now depend on mechanical draught equipment rather than natural draught. This is because natural draught is subject to outside air conditions and temperature of flue gases leaving the furnace, as well as the chimney height. All these factors make proper draught hard to attain and therefore make mechanical draught equipment much more economical.

Feed water and steam circuit :-

The steam produced in the boiler is supplied to the turbines to generate power. The steam that is expelled by the prime mover in the thermal power plant layout is then condensed in a condenser for re-use in the boiler. The condensed water is forced through a pump in to the feed water heaters where it is heated using the steam from different points in the turbine. To make up for the lost steam and water while passing through the various components of the thermal power plant layout, feet water is supplied through external sources. feed water is purified in a purifying plant to reduce the dissolve salts that could scale the boiler tubes.

BINARY VAPOUR CYCLE :-

It is one type of combined cycles in which usually two working fluids mercury and water are used to improve the overall thermal efficiency of the power plant



For getting the best performance of vapour power cycle, the working fluid should have the following characteristics.

1. High enthalpy of vaporization
2. Good heat transfer characteristic
3. High critical temperature with a low corresponding saturation temperature.
4. High condenser temperature.
5. freezing temperature should be below room temperature and 5-7. The process 7-8 represents the pumping process of feed water in the feed pump.

Let m = mass of mercury in the mercury cycle / kg of steam circulated

Heat supplied $(Q_s) = m \times (h_1 - h_4) + (h_5 - h_9)$

Workdone by mercury turbine/kg of steam Generated ; $W_{T_m} = (h_1 - h_2)$

Workdone by the steam turbine/kg of steam generated

$$W_{T_s} = h_5 - h_6$$

Heat rejected $Q_R = h_6 - h_7$

Total workdone in binary cycle

$$W_T = W_{T_m} + W_{T_s}$$

pump work $W_P = m(h_4 - h_3) + (h_8 - h_7)$

Overall efficiency of the binary cycle

$$\eta_{binary} = \frac{W_{Tm} + W_{St}}{Q_s}$$

Specific steam rate,

$$SSR = \frac{3600}{W_T - W_p} \; kg/kWh$$

Thermal efficiency of the mercury cycle,

$$\eta_{binary} = \frac{m \times W_{Tm}}{m \cdot h_1} = \frac{W_{Tm}}{h_1}$$

Efficiency of steam cycle,

$$\eta_{binary} = \frac{W_{Ts}}{h_5 - h_8}$$

The value of m can be determined from energy balance equation.

$$m(h_2 - h_3) = (h_9 - h_8)$$

Mass flow rate of mercury required/kg of steam flow rate

$$m = \frac{h_9 - h_8}{h_2 - h_3}$$

COGENERATION SYSTEMS :-

Cogeneration is also called Combined heat power. Cogeneration works based on the Concept of producing two different form of energy by using a single source of fuel. Out of these two forms one must be heat or thermal energy and other one is either electrical or Mechanical energy. Cogeneration is the most optimum, reliable clean and efficient way of utilizing fuel. The fuel used may be natural gas, oil, diesel, propane, wood, bagasse, coal etc.

It working principle is simple. In this case, the fuel is used to generate electricity and. this electricity produces heat and this heat is used to boil the water to produce steam for space heating and

UNIT II
DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS

INTRODUCTION TO GAS POWER CYCLES :-

Thermodynamic cycle is defined as the series of operations or processes performed on a thermal system so that the system attains its original state. The cycles which use air as the working fluid are known as gas power cycles. The sources of heat supply and the sink for the heat rejection are assumed to be external to the air. The cycle can usually be represented on P-V and T-S diagrams.

The following assumptions are made in the analysis of gas power cycles.

... the working medium is a perfect gas through out i.e.) It follows the law $pv = mRT$

2. The working Medium has constant specific heats.

3. Kinetic and potential energies of the working fluid are neglected.

SOME IMPORTANT PARAMETERS :-

(i) Air Standard efficiency (η) :-

It is the ratio of work done to the heat supplied during the process.

$$\text{Air standard Efficiency } \eta = \frac{\text{Workdone}}{\text{Heat supplied}} = \frac{W}{Q_S}$$

where Workdone = Heat supplied - Heat rejected

$$W = Q_S - Q_R$$

(ii) Mean Effective pressure (P_m) :-

The average pressure developed throughout a cycle of operation is called mean effective pressure. In other words, it is the ratio of work done to the swept volume.

$$\text{Mean Effective pressure } (P_m) = \frac{\text{Workdone}}{\text{Swept volume}} = \frac{W}{(V_1 - V_2)}$$

$$\text{Also, Mean effective pressure } (P_m) = \frac{\text{Area of the } p\text{-}V \text{ diagram}}{\text{Length of the diagram}}$$

(iii) Power (P) :-

It is defined as the amount of workdone for the unit mass flow rate of the working substance.

power = work done × Mass flow rate of working substance

$$P = W \times m_f$$

OTTO CYCLE :-

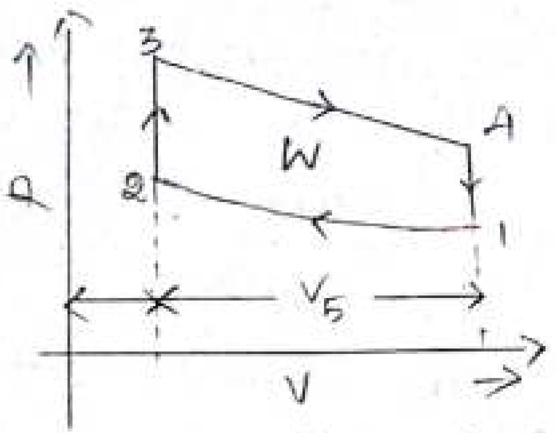
The cycle which was introduced by Dr. A.N. Otto, a German scientist is called ... Generally, petrol and gas engines ...

follows this ... following four processes.

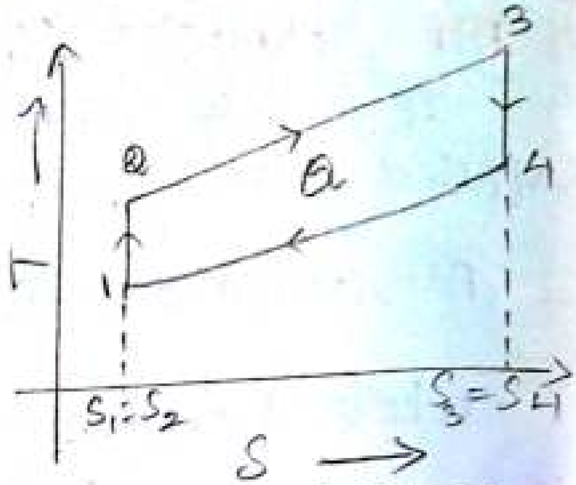
1. Two reversible adiabatic or isentropic processes, and

2. Two constant volume processes.

p-V and T-s diagrams are as shown as



p-V diagram



T-s diagram

Process 1-2 :-

Process 1-2 is the isentropic compression process. During this process, pressure increases from p_1 to p_2 and temperature increase from T_1 to T_2. But, the volume decreases from V_1 ... and the entropy remains constant

(ie) $S_1 = S_2$

Process 2-3 :-

Process 2-3 is a constant volume heat addition process. During this process, pressure increases from p_2 to p_3; temperature increases from T_2 to T_3 and entropy increases from S_2 or S_1 to S_3 (since $S_1 = S_2$). But the volume remains constant (ie) $V_2 = V_3$

Process 3-4 :-

Process 3-4 is an isentropic expansion process. During this process, pressure decreases from p_3 to p_4; temperature decreases from T_3 ... and volume increase from V_3 to V_4. But, the entropy remains constant (ie) $S_3 = S_4$)

... constant volume heat rejection process. During this process, pressure decreases P_4 to P_1, temperature decreases from T_4 to T_1, and entropy decreases from S_4 to S_1 or S_3 to S_1 (since $S_3 = S$). But the volume remains constant (ie) $V_4 = V_1$)

Heat is rejected during 4-1 process,

$$Q_R = m \times C_v (T_4 - T_1) \text{ in kJ}$$

workdone during cycle W } = Heat supplied − Heat rejected

$$= Q_S - Q_R$$

$$= m \times C_v (T_3 - T_2) - m \times C_v (T_4 - T_1)$$

Efficiency ; $\eta_{otto} = \frac{Q_S - Q_R}{Q_S}$

$$= \frac{m C_v (T_3 - T_2) - m C_v \cdot (T_4 - T_1)}{m C_v (T_3 - T_2)}$$

$$\eta_{otto} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

This expression is in terms of temperature only. If the temperatures at all points of the cycle are known, then only the above equation can be used. Hence, the efficiency equation is simplified in terms of volume ratio

From p-V diagram

Total cylinder volume $= V_1 = V_4$

Clearance volume $= V_C = V_2 = V_3$

stroke volume $= V_S = V_1 - V_2 = V_4 - V_3$

Compression ratio (r) :-

compression ratio (r) is the ratio between the total cylinder volume and clearance volume

$$\text{compression ratio } r = \frac{V_1}{V_2}$$

Adiabatic compression ratio

Total cylinder volume

$$r = \frac{V_1}{V_2} = \frac{V_4}{V_3}$$

During the adiabatic process, the compression ratio is equal to expansion ratio.

Consider the process 1-2 :-

The adiabatic relation between T and v is given by

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r)^{\gamma-1}$$

$$T_2 = T_1 \times (r)^{\gamma-1}$$

Consider the process 3-4 :-

The adiabatic relation between T and v is given by

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = (r)^{\gamma-1}$$

$$T_3 = T_4 \times (r)^{\gamma-1}$$

Substituting T_2 and T_3 values in equation

$$\eta_{otto} = 1 - \frac{T_4 - T_1}{T_4(r)^{\gamma-1} T_1(r)^{\gamma-1}}$$

$$= 1 - \frac{T_4 - T_1}{(T_4 - T_1)(r)^{\gamma-1}}$$

$$\eta_{otto} = 1 - \frac{1}{(r)^{\gamma-1}}$$

from above equation, the efficiency of otto cycle increase with increase in compression ratio and viceversa.

Mean effective pressure (P_m) :-

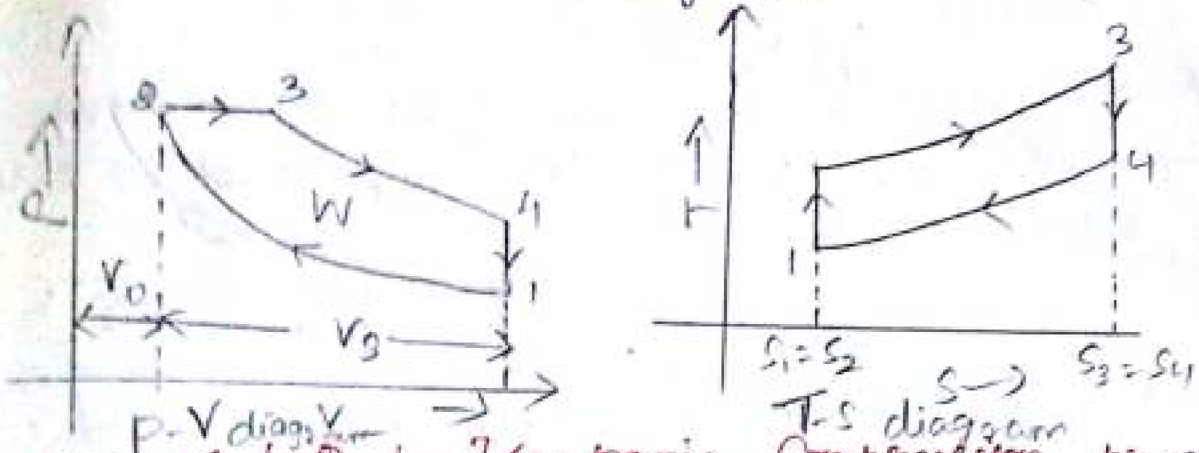
$$P_m = P_1 r \left(\frac{k-1}{\gamma-1}\right)\left(\frac{r^{\gamma-1}-1}{r-1}\right)$$

DIESEL CYCLE :-

This is the cycle which was introduced by Rudalph Diesel. This cycle is used in Diesel engines. It consists of the follo four processes.

1. Two reversible adiabatic or isentropic
2. One constant volume, and
3. One constant pressure processes.

p-V and T-s diagrams



Process 1-2 :- Isentropic Compression process :-

During the process, the air is isentropically compressed from P_1 to P_2. But the entropy remains constant ($S_1 = S_2$)

Process 2-3 :- Constant pressure head addition process :-

During the process, the air is heated from T_2 to T_3 but the pressure remains constant ($P_2 = P_3$)

Heat supplied during the process

$$Q_S = m \times C_p (T_3 - T_2)$$

Process 3-4 : Isentropic expansion process :-

During this process, the air Isentropically expands from P_3 to P_4. But the temperature decreases from $T_3 - T_4$

Process 4-1 :- constant volume heat rejection process :-

During this process, the heat is rejected from air but the volume remains constant. Thus, the temperature decreases from T_4 to T_1

Heat rejected $Q_R = m \times C_V (T_4 - T_1)$

Efficiency of Diesel cycle.

$$\eta_{d} = \frac{Q_S - Q_R}{}$$

$$= \frac{mC_p(T_3-T_2) - mC_v(T_4-T_1)}{mC_p(T_3-T_2)}$$

$$= 1 - \frac{mC_v(T_4-T_1)}{mC_p(T_3-T_2)}$$ $\left[\because \frac{C_p}{C_v} = \gamma\right]$

$$\eta_{Diesel} = 1 - \frac{(T_4-T_1)}{\gamma \times (T_3-T_2)}$$

The efficiency is in terms of temperature only. Hence, the equation is simplified in terms of volume ratio

Compression ratio = $\frac{\text{Total cylinder volume}}{\text{Clearance volume}} = \frac{V_1}{V_2} = r$

Cut-off ratio is the ratio between the volume at the point of cut off and clearance volume. It is denoted by 'ρ'

Cut-off ratio $\rho = \frac{\text{Cut-off volume}}{\text{Clearance volume}} = \frac{V_3}{V_2}$

Expansion ratio $= \frac{V_4}{V_3} = \frac{V_1}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_3} = r \times \frac{1}{\rho} = \frac{r}{\rho}$

Consider process 1-2 :-

From adiabatic relation $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r)^{\gamma-1}$

$$T_2 = T_1 \times (r)^{\gamma-1}$$

Consider process 2-3 :-

Process 2-3 is a constant pressure process.

so, $\frac{V}{T} = C$

$$\frac{V_2}{T_2} = \frac{V_3}{T_3}$$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2} = \rho$$

$$T_3 = T_2 \times \rho = T_1 (r)^{\gamma-1} \rho \qquad (\because T_2 = T_1 (r)^{\gamma-1})$$

$$T_3 = T_1 (r)^{\gamma-1} \rho$$

Consider process 3-4 :-

Using adiabatic equation

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{r}{\rho}\right)^{\gamma-1}$$

$$T_4 = \frac{T_3}{\left(\frac{r}{\rho}\right)^{\gamma-1}} = \frac{T_1 (r)^{\gamma-1} \rho}{\left(\frac{r}{\rho}\right)^{\gamma-1}}$$

$$T_4 = \frac{T_1 (r)^{\gamma-1} \rho \rho^{\gamma-1}}{(r)^{\gamma-1}}$$

$$T_4 = T_1 \rho^{\gamma}$$

substituting T_2, T_3 and T_4 values in η_{Diesel} equation

$$\eta_{Diesel} = 1 - \frac{1}{\gamma}\left[\frac{T_1 \rho^{\gamma} - T_1}{T_1 (r)^{\gamma-1} \rho - T_1 (r)^{\gamma-1}}\right]$$

$$= 1 - \frac{1}{\gamma}\left[\frac{T_1(\rho^{\gamma}-1)}{T_1 r^{\gamma-1}(\rho-1)}\right]$$

$$\eta_{Diesel} = 1 - \frac{1}{\gamma r^{\gamma-1}}\left(\frac{\rho^{\gamma}-1}{\rho-1}\right)$$

from above equation

1. If the Compression ratio increases, the efficiency of Diesel cycle is increased and vice versa
2. The efficiency of Diesel cycle decreases with increase in cutoff ratio and vice versa

Mean effective pressure (P_m) :-

$$P_m = \frac{P_1 r^{\gamma}\left[\gamma(\rho-1) - r^{1-\gamma}(\rho^{\gamma}-1)\right]}{(\gamma-1)(r-1)}$$

DUAL CYCLE :-

In earlier otto and Diesel cycles, the heat addition takes place at both constant volume and constant pressure processes. Dual cycle is the combination of above two cycles because the heat addition takes place partially at constant volume and remaining at constant pressure. Therefore, it is also called as mixed cycle or limited pressure cycle. This cycle consists of the following processes.

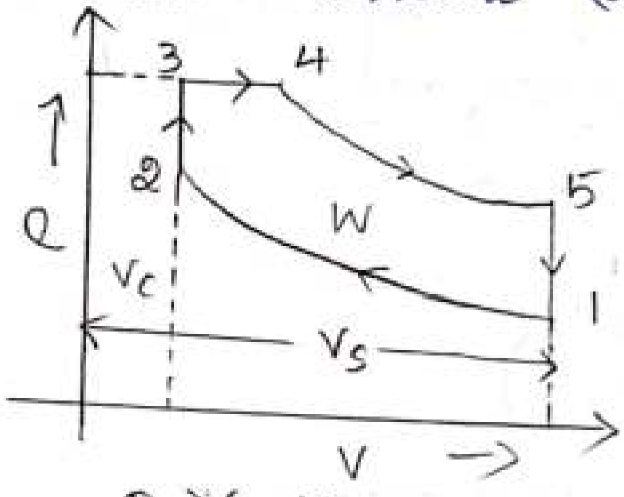
1. Two reversible adiabatic or isentropic processes

2. One constant pressure process

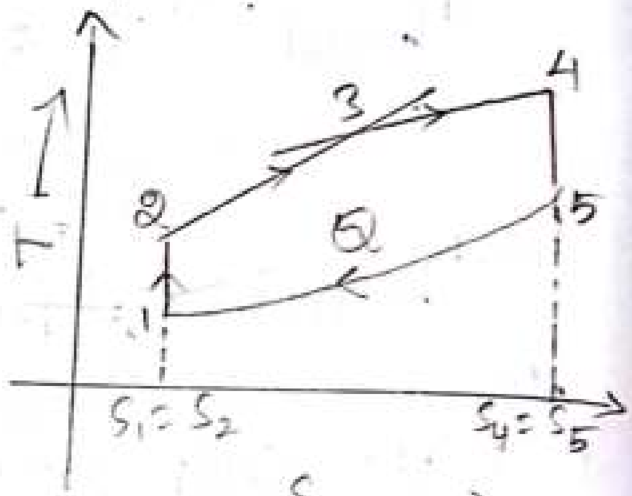
p–V and T–s diagrams

Process 1-2 :- Isentropic compression process :-

During the process, the air is isentropically compressed from P_1 to P_2. But, the entropy remains constant (ie) $s_1 = s_2$



P–V diagram



T–s diagram

Process 2-3 :- Constant volume heat addition process :-

During the process, the compressed air is partially heated by constant volume process (ie) $v_2 = v_3$. Both temperature and entropy increase from T_2 to T_3 and s_2 to s_3 respectively.

Heat supplied during the process

$$Q_{s_1} = m \times C_v (T_3 - T_2)$$

Process 3-4 :- Constant pressure heat addition process

During the process, the partially heated air is again heated by constant pressure process (ie) $P_3 = P_4$. Both temperature and entropy increase from T_3 to T_4 and S_3 to S_4 respectively.

Heat supplied during the process,

$$Q_{s_2} = m \times C_p (T_4 - T_3)$$

... P_4 to P_5 and the ... isentropically decreases from T_4 to T_5 and the temperature

process 5-1 :- Constant volume heat rejection process :-

During the process, the heat is rejected from the air and the volume remains constant (i.e) $v_5 = V_1$. Thus temperature decreases T_5 to T_1 and entropy decreases S_5 to S_1.

$$Q_R = m \times C_v (T_5 - T_1)$$

The total heat supplied during heat addition is the sum of the heat supplied at constant volume and constant pressure processes

$$Q_S = Q_{S1} + Q_{S2} = m \times C_v (T_3 - T_2) + m \times C_p (T_4 - T_3)$$

Air standard efficiency

$$\eta = \frac{W}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$= \frac{mC_v (T_3 - T_2) + mC_p (T_4 - T_3) - mC_v (T_5 - T_1)}{mC_v (T_3 - T_2) + mC_p (T_4 - T_3)}$$

$$\eta = 1 - \frac{(T_5 - T_1)}{(T_3 - T_2) + \gamma (T_4 - T_3)} \qquad \left(\because \frac{C_p}{C_v} = \gamma\right)$$

The above efficiency equation is in terms of temperatures.

compression ratio; $r = \frac{V_1}{V_2}$

pressure ratio, $K = \frac{P_3}{P_2}$

cut-off ratio, $\rho = \frac{V_4}{V_3}$

Expansion ratio, $\frac{V_5}{V_4} = \frac{V_1}{V_4} = \frac{V_1}{V_2} \times \frac{V_2}{V_4}$ $\left(\because V_5 = V_1,\ V_3 = V_2\right)$

$$= \frac{V_1}{V_2} \times \frac{V_3}{V_4} = \frac{r}{\rho}$$

Consider process 1-2 :- $T_{..}$ $(\frac{V_1}{..})^{\gamma-1} = (r)^{\gamma-1}$

Consider process 2-3

Constant volume process, $\frac{P_2}{T_2} = \frac{P_3}{T_3}$

$$T_3 = \frac{P_3}{P_2} T_2 = K . T_1 (r)^{\gamma-1}$$

Consider process 3-4 :-

Constant pressure process, $\frac{V_3}{T_3} = \frac{V_4}{T_4}$

$$T_4 = \frac{V_4}{V_3} T_3 = P . K . T_1 (r)^{\gamma-1}$$

Consider process 4-5 :-

Isentropic process,

$$\frac{T_4}{T_5} = \left(\frac{V_5}{V_4}\right)^{\gamma-1} = \left(\frac{r}{\rho}\right)^{\gamma-1}$$

$$T_5 = \frac{T_4}{\left(\frac{r}{\rho}\right)^{\gamma-1}} = \frac{T_4 \rho^{\gamma-1}}{(r)^{\gamma-1}} = \frac{T_1 (r)^{\gamma-1} K . P . \rho^{\gamma-1}}{(r)^{\gamma-1}}$$

$$T_5 = T_1 K \rho^{\gamma}$$

Note :-

$T_2 = T_1 (r)^{\gamma-1}$

$T_3 = K . T_1 (r)^{\gamma-1}$

$T_4 = P . K . T_1 (r)^{\gamma-1}$

$T_5 = T_1 K . \rho^{\gamma}$

Substituting T_2, T_3, T_4, T_5 in η equation

$$\eta = 1 - \frac{T_1 K \rho^{\gamma} - T_1}{[T_1 (r)^{\gamma-1} K - T_1 (r)^{\gamma-1}] + \gamma [T_1 (r)^{\gamma-1} K \rho - T_1 (r)^{\gamma-1} K]}$$

$$= 1 - \frac{T_1 [K \rho^{\gamma} - 1]}{T_1 (r)^{\gamma-1} [(K-1) + \gamma K (\rho - 1)]}$$

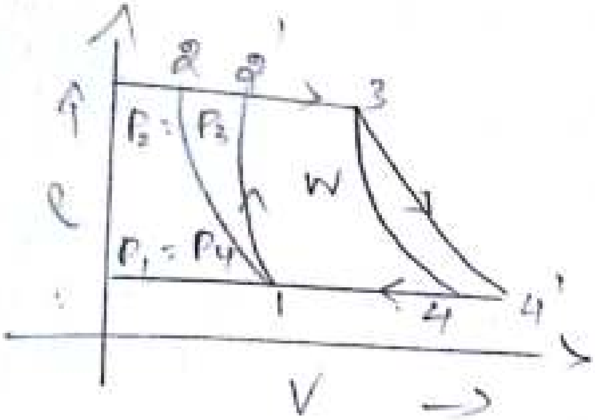
$$\eta_{dual} = 1 - \frac{1}{(r)^{\gamma-1}} \left[\frac{K \rho^{\gamma} - 1}{(K-1) + \gamma K (\rho - 1)}\right]$$

Mean effective pressure (P_m) :-

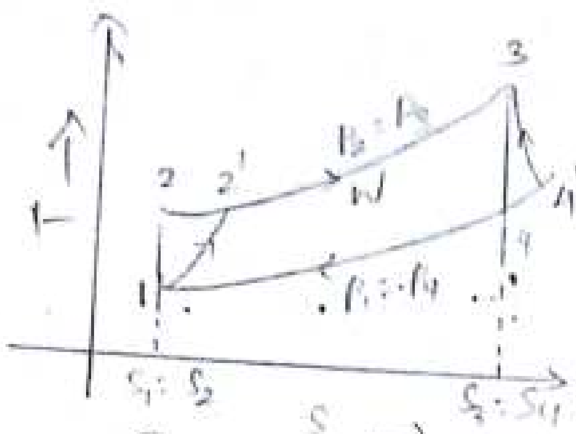
$$P_m = \frac{P_1 r^{\gamma} [K \gamma (\rho - 1) + (K-1) - r^{1-\gamma} (K \rho^{\gamma} - 1)]}{(\gamma - 1)(r - 1)}$$

ANALYSIS OF BRAYTON CYCLE :-

In an ideal cycle, both compression and expansion processes are reversible adiabatic. But in actual practice it is not possible to achieve a reversible process because of friction and unaccounted heat losses in both turbine and compressor. Therefore, an actual gas turbine plant differs from ideal one.



p-V diagram



T-s diagram

In above diagram the ideal process is represented by 1-2-3-4 lines and the actual process is represented by 1-2'-3-4' lines.

work required by compressor, $W_c = m \times c_p (T_2' - T_1)$

work done by the turbine, $W_T = m \times c_p (T_3 - T_4')$

$\therefore$ Net work available $W = W_T - W_C$

$= m \times c_p [(T_3 - T_4') - (T_2' - T_1)]$

Net heat supplied $Q_s = m \times c_p (T_3 - T_2')$

Thermal efficiency for actual cycle.

$$\eta_{th} = \frac{W}{Q_s} = \frac{(T_3 - T_4') - (T_2' - T_1)}{T_3 - T_2'}$$

Isentropic efficiency of the

compressor $\eta_c = \frac{T_2 - T_1}{T_2' - T_1}$,

turbine, $\eta_T = \frac{T_3 - T_4'}{T_3 - T_4}$

The net output of the cycle is reduced by the amount $[(h_4' - h_4) + (h_2' - h_2)]$ and the heat supplied is reduced by the amount $(h_2' - h_2)$

The efficiency of the cycle is less than the ideal cycle.

OPTIMISATION OF BRAYTON CYCLE:

The pressure ratio at which the work ... is known as optimum the optimum pressure ratio of the cycle is

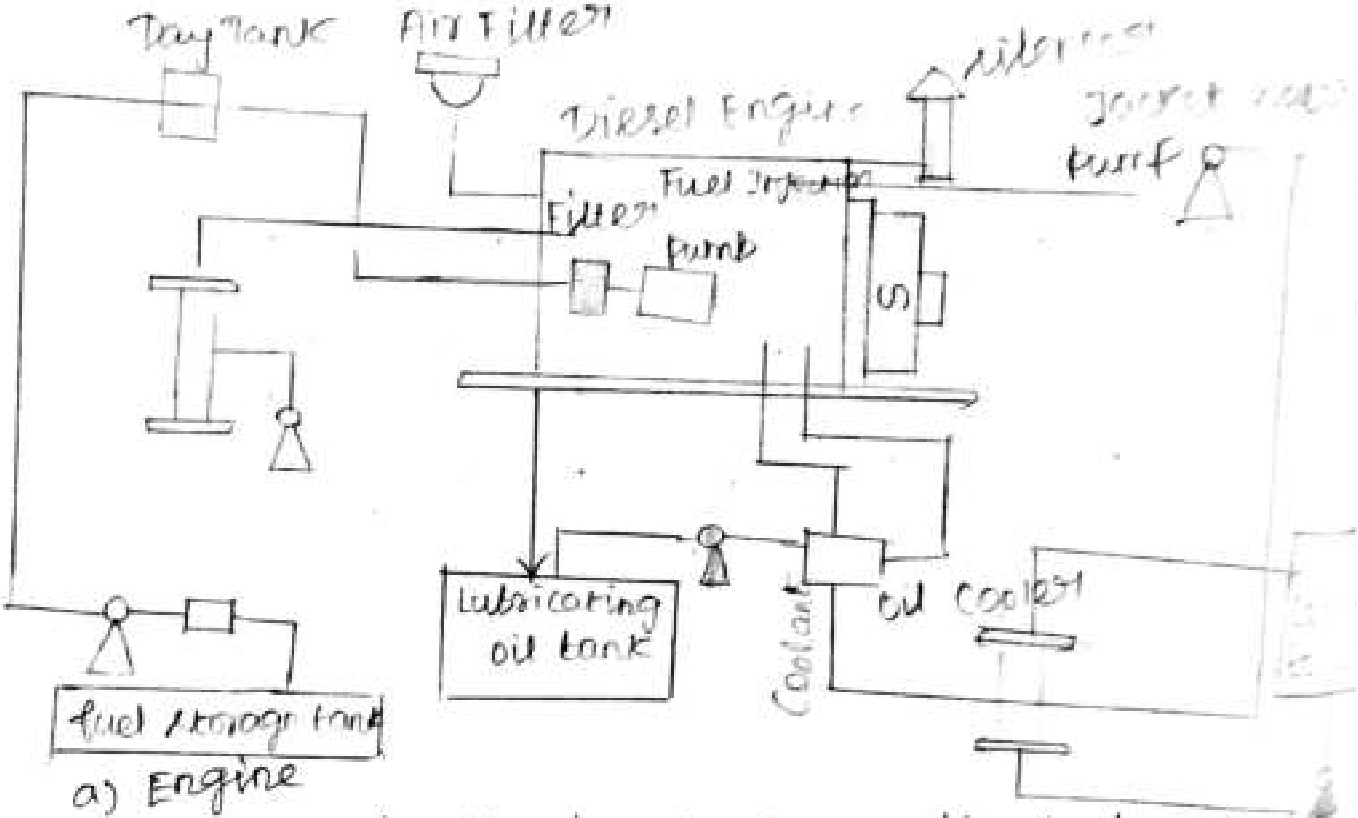
$$\left(\frac{P_2}{P_1}\right) = \left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$(R_p)_{opt} = \left[\frac{(T_1 \times T_3)^{1/2}}{T_1}\right]^{\frac{\gamma}{\gamma-1}}$$

$$(R_p)_{opt} = \left[\frac{T_3}{T_1}\right]^{\frac{1}{2} \times \frac{\gamma}{\gamma-1}}$$

The optimum pressure can also be obtained by differentiating the network output with respect to the pressure ratio and putting the derivative equal to zero.

DIESEL POWER PLANT :-



a) Engine

Engine is the heart of a diesel power plant. Engine is directly connected through a gear box to the generator. Generally two-stroke engines are used for power generation. Now a days advanced super & turbo charged high speed engine are available for power production.

b) Air supply system :

Air Inlet is arranged outside the engine filter and conveyed to the inlet manifold of engine. In Large plants supercharger/turbo charger is used for increasing the pressure of input air which increase the power output

c) Exhaust system :-

This includes the silencers and connecting ducts. The heat content of the exhaust gas is utilized in a turbine in a turbo charger to compress the air input to the engine.

d) fuel system :-

fuel is stored in a tank from where it flows to the fuel pump through a filter. fuel is injected to the engine as per load requirement.

e) Cooling system :-

This system includes water circulating pumps, cooling towers, water filter etc. cooling water is circulated through the engine block to keep the temperature of the engine in the safe range.

f) Lubricating system :-

Lubrication system includes the air pumps, oil tanks, filters, coolers and pipe lines. Lubricant is given to reduce friction of moving parts and reduce the wear and tear of the engine parts.

g) starting system :-

There are three commonly used starting systems.

1) A petrol driven auxiliary engine
2) use of electric motors
3) use of compressed air from an air compressor at a pressure of 20 kg/cm²

UNIT II
NUCLEAR POWER PLANTS

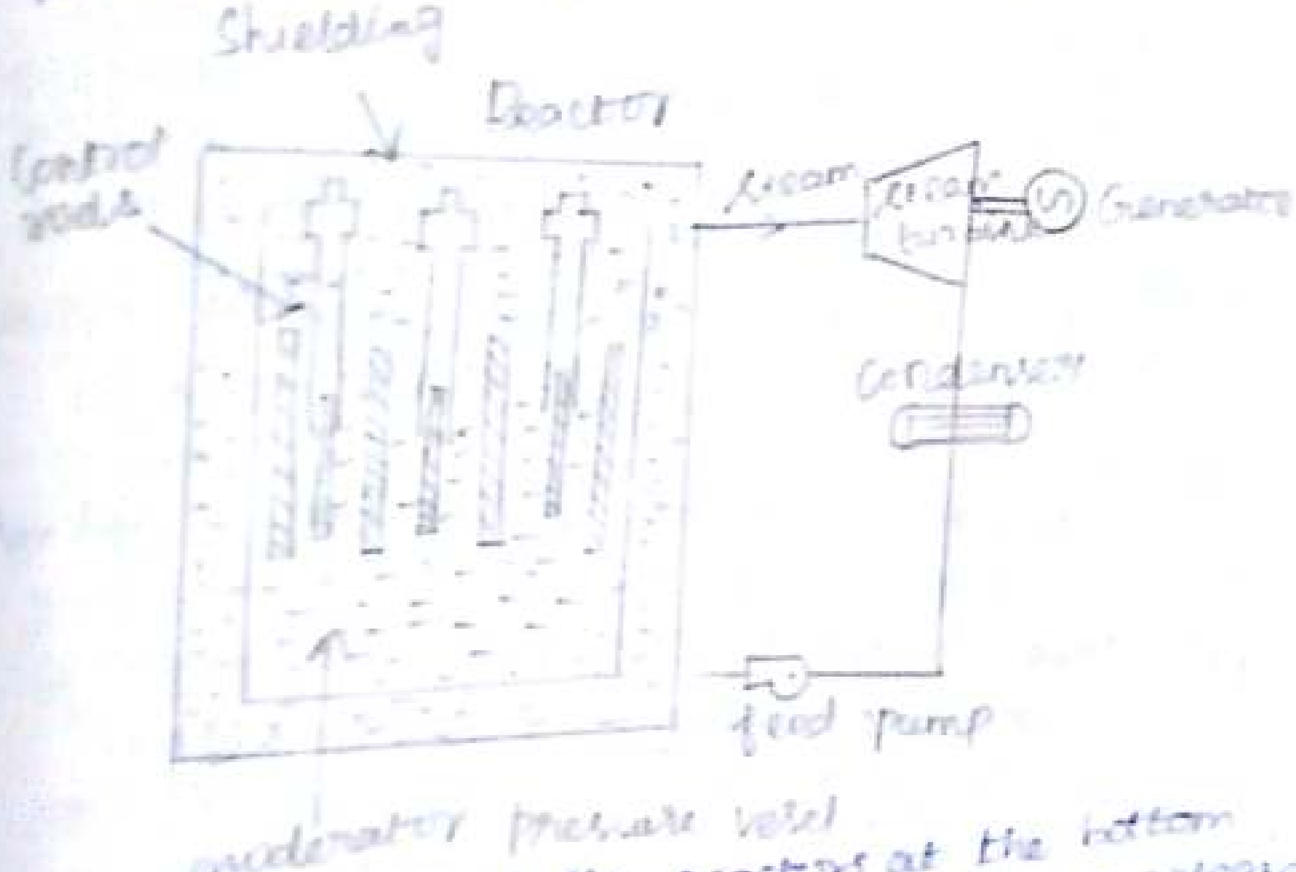
Introduction :

The world needs more energy. Energy multiplies human labour and increases the productivity. It builds and lights schools, purifies water, power farm machinery, drives sewing machines and robot assemblers, stores and moves information. World population is steadily increasing having passed six billion in 1999.

The nuclear chain reaction and nuclear explosion were predicated in 1939 by German scientists. The invention has given a great confidence of producing nuclear energy from nuclear fission of materials such as Uranium, plutonium etc

BOILING WATER REACTOR (BWR)

The arrangement of boiling water reactor is simple when compared to a pressurised water reactor. The nuclear power plant using boiling water reactor. In this type of reactor, Enriched Uranium is used as a fuel and water is used as a moderator, coolant and reflector in PWR. The only difference between PWR and BWR is in a B.W.R the steam is generated in the reactor itself instead of a separate steam generator.



Water enters the reactors at the bottom. This water is heated by the heat released due to this fission of fuel and it gets converted into steam. The steam which leaves the top of the reactor is passed through the turbine and it gets expanded.

India's first nuclear power plant at Tarapur has two B.W.R.S of 200 MW capacity each.

Advantages :-

1. some intermediate heat exchange equipment is eliminated.

2. The reactor vessel is much lighter than PWR since the pressure inside the reactor is less

3. The metal temperature remains low for the given output condition.

4. It has negative temperature co-efficient

5. Ordinary leakage can be tolerated.

Disadvantages :-

1) It produces lower power density (33.6 kW/Litre) and large in size.

2. power demand fluctuations cannot be met.

3. fuel must be at least slightly enriched

4. fuel handling necessitates complex equipment.

5. Reactor must be shut down to unload and reload core.

pressurized water Reactor :-

Constitute a majority of all western nuclear power plants and are one of two types of light water reactor; the other type being boiling water Reactors (BWRs). In a PWR the primary coolant is pumped under high pressure to the reactor core where it is heated by the energy generated by the fission of atoms. The heated water then follows to a 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

... similar to a boiling water reactor, pressure in the primary coolant loop prevents

the water reactor, pressure in the primary coolant loop prevents the water from boiling with in the reactor. All LWRS use ordinary light water as both coolant and neutron moderator PWRs were originally designed to serve as nuclear propulsion for nuclear submarines and were used in the original design of the second commercial power plant at shipp ingport Atomic power station.

PWRs currently operating in the united states are considered Generation II reactors. Russia's VVER reactors are similar to U-S PWRs france operates many PWRs to generate the bulk of their electricity

The first commercial Nuclear plant at shippingport Atomic power station was originally designed as a pressurized water reactor, on resistance from Admiral Hyman G. Rickover that a viable commercial plant would include none of the crazy thermodynamic cycles that everyone else wants to build.

Safety measures for nuclear power plants:

Nuclear power plants in Japan have multiple safety measures, which are designed on the assumption that they must ensure the safety of the neighboring communities so that there will be no adverse impacts on their health.

Nuclear power plants are designed to prevent abnormal incidents from occurring. Even if abnormal incidents occur, nuclear plants are also designed to prevent the potential spreading of abnormal incidents and leakage of radioactive materials around plants, which may cause adverse impacts on the surrounding environment.

Japanese power plants utilize redundant safety measures to keep residential communities around them safe at all times. Measures

1. To shut down operating reactors
2. To cool down reactors so as to remove heat from nuclear fuel
3. To contain radio active materials.

Nuclear operators monitor environmental radiation around their facility and radio activity in environmental samples in order to confirm that there is no harmful effect on the surrounding environment.

To enable these efforts to be constantly and objectively evaluated, the Japan Nuclear Safety Institute (JANSI) evaluating the safety improvement activities of electric power companies and giving them technical advice and the Nuclear Risk Research Center (NRRC) using probabilistic Risk Assessment and proposing solutions based on R&D, were established. The electric power companies take to heart the evaluations and recommendations and are striving to achieve the highest safety level in the world.

Components of Nuclear safety :-

There is a way of grouping the elements of nuclear safety into three components as follows.

(i) Technical safety

(ii) Human factors and organizational safety, and

(iii) programmatic and cross - cutting safety.

Components of Technical safety :-

(i) A solid foundation of knowledge of the basic physics, Chemistry and engineering of nuclear technology.

(ii) A robust facility design which uses established cods and standards that embody design margins, qualified materials, redundant and diverse safety systems.

(iii) A strong engineering function maintains the plant systems and equipment in accordance with the facility design and it provides a good support to operations and maintenance.

(iv) Safety assessments of all changes and back fits are made during the life of the facility.

(v) A programme for utilizing the probabilistically developed risk insights derived from systems analysis and operational experience.

Components of Human factors and organizational Safety :-

(i) sufficient properly qualified, trained and fit-for-duty personnel to operate the facility maintain the equipment and implement the radiation protection programme.

(ii) A comprehensive set of operating, maintenance, and accident management procedures including severe accident management guide-lines.

(iii) A strong corporate management organization with a leadership establishes a set of values emphasizing the priority of nuclear safety.

(iv) A facility management organization has clear lines of authority and responsibilities for safety and strict adherence to safety procedures.

(v) A programme and procedures for the management oversight all safety-related workdone by contract workers.

components of programmatic and cross-cutting safety

(i) operational limits and conditions (or technical specifications) define and govern the safe operating envelope of the facility and ensure the radiation exposures as low as reasonably achievable.

(ii) A programme of operating experience analysis, trending analysis and feedback to operations are defined

(iii) A configuration management programme maintains the safety design basis of the facility as approved by the regulatory body.

(iv) A change management programme ensures the organizational change not inadvertently diminishing with operational safety.

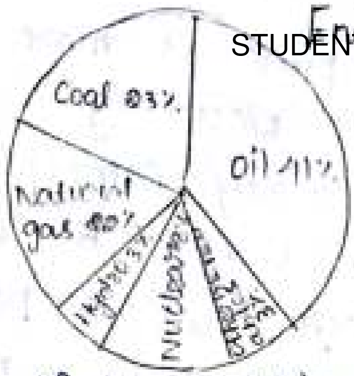
(v) A programme of initial and continuing training are ensured for operating staff of qualified workers

(vi) facility sitting and environmental policies promote offsite protection.

(vii) security plans are tested and kept current to prevent threats to the facility and unauthorised use of nuclear materials.

In addition to above safety elements that apply to operation of a nuclear facility, there must be a safety regulatory body which has the legal authority, technical competence and adequate resources to independently assure to design, built, operate and decommission nuclear facilities safely.

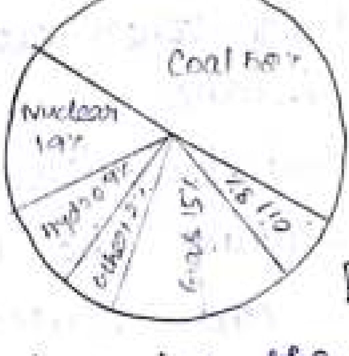
... NUCLEAR ENERGY TODAY :



Energy production.

Most of the world's energy today comes from petroleum; coal (24%); natural gas (22%), hydroelectric power (6.9%) and nuclear power (6.3%) Although oil and coal still dominate, their market fraction begins to decline few decades ago. Meanwhile, natural gas and nuclear power have steadily increased their shares and they should continue to do so. with 433 operating reactors world wide, nuclear power is meeting the annual electrical needs of morethan a billion people.

In America and around the globe, nuclear safety and efficiency have improved significantly since 1990. In 1998 and 1999, the unit capacity factor for operating reactors reached the record level. The average US capacity factor in 1999. was 85% for about 100 reactors, compared to 58% in 1980 and 66% in 1990. Despite a reduction occurs in the number of power plants, US nuclear Industry is generating 9% more nuclear electricity in 1999 than in 1998. Average production costs for nuclear energy are now Just 1.9 cents per kilowatt-hour (kwh) while electricity produced from gas costs 3-4 cents per kwh



Electricity production

By improving the capacity and performance alone, nuclear power has already made the largest contribution of any American Industry to meet US Kyoto commitment in limiting Carbon dioxide release to the atmosphere.

Although the new nuclear power is more expensive, the production cost of nuclear electricity generated from existing US plants is already competitive with electricity from fossil fuels. But this higher price tag is deceptive to end users. Large nuclear power plants require larg capital investments than comparable coal or gas plants because nuclear utilities are required to build and maintain costly systems to keep their radioactivity from the environment.

If fossil-fuel plants were similarly required to sequeeze the pollutants what they generate, they would significantly cost more pollution than nuclear power plants.

ELEMENTARY TREATMENT OF NUCLEAR ENGINEERING

Atomic structure :-

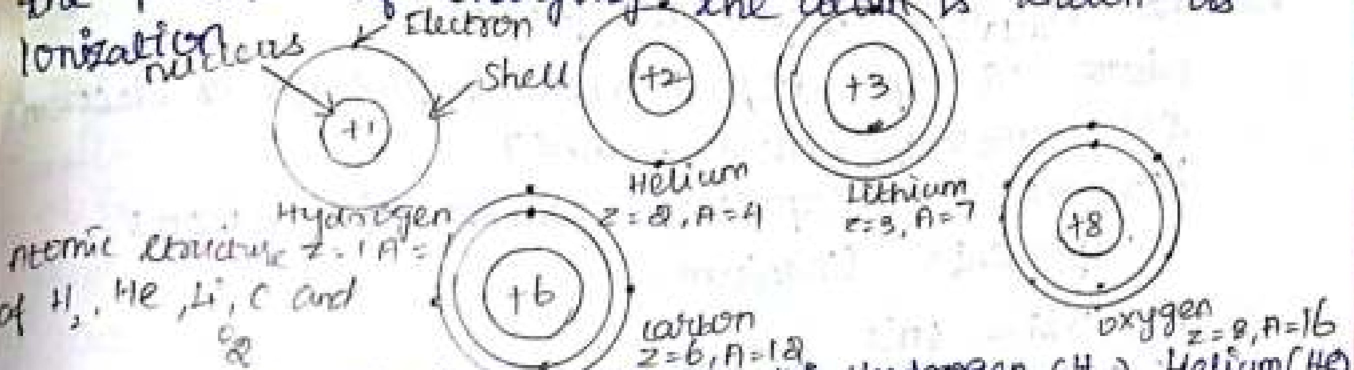
An element is defined as a substance which cannot be decomposed into other substance. The smallest particle of an element, which takes a part in chemical reaction is known as 'atom'

According to Dalton's atomic theory

1. All atoms of one element are precisely alike even if they have the same mass. It only differs the atoms of other elements.
2. The chemical combination consists of the union of small fixed number of atoms of one element with a small fixed number of other elements.

The atom of any substance consists of positively charged nucleus and the negatively charged electron orbiting around the nucleus. The nucleus consists of protons and neutrons. The neutron has a mass but neutral electric charge. The proton also possesses a mass but it carries a positive charge equal and opposite to electron.

... charge on proton is equal to the negative charge on electron and the number of electrons is equal to the number of protons, atom is a neutral element. Any addition of election to the neutral atom makes the atom negatively charged. Similarly, any subtraction of election will make it positively charged. Such atom is known as Iron and the process of charging the atom is known as Ionization.



atomic structure of H_2, He, Li, C and O_2

The atomic structure of Hydrogen (H_2), Helium (He), Lithium (Li), oxygen (O_2) and carbon (C) elements. Hydrogen consists of one electron in the first shell, Helium has two electrons in the first shell, Lithium has two electrons in the first shell and one in the second shell, oxygen consists of two electrons in the first shell and six in the second shell and Carbon has two electrons in the first shell and four in the second shell.

Atomic Number and Mass Number :-

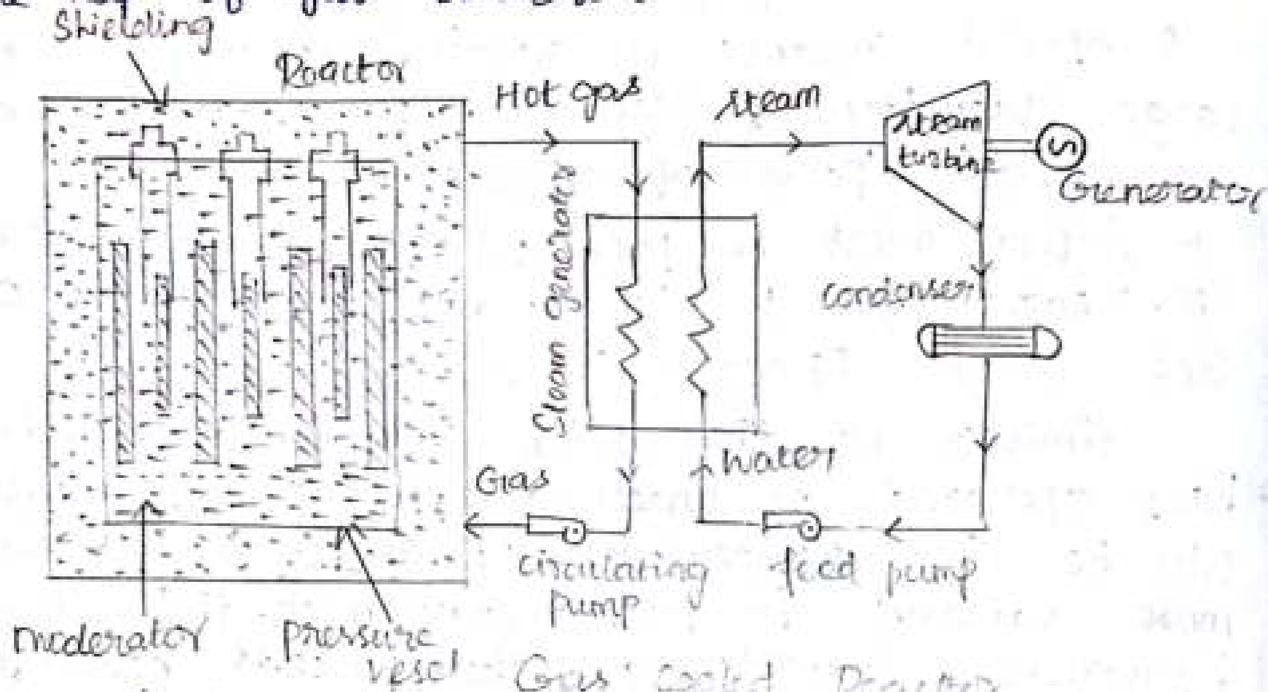
The number of protons in the nucleus is called atomic number. It is denoted by 'Z'. The total number of nucleons in the nucleus is called mass number. It is denoted by a letter 'A'. A nuclear symbol is written conveniently as

$$Z^A$$

The difference between mass number and atomic number gives the number of neutrons (N) in the nucleus of atom.

Isotopes :-

Some elements exist in different forms. The mass number of these different forms in different is heated by the heat released by the fission of fuel and it leaves the reactor at the top and it flows to heat exchanger. In the heat exchanger hot gas transfers its heat to water which gets converted into steam. The gas is recirculated with the help of gas blowers.



Gas cooled Reactor

this steam is passed through the turbine and expanded to produce mechanical work. Exhaust steam from the turbine is condensed with the help of a condenser.

Advantages :-

1. fuel processing is simpler than other reactors
2. Corrosion by coolant is negligible
3. coolant doesn't react with fuel or with other core materials.
4. coolant has very low capture cross section.
5. Coolant is cheap.
6. Gas turbine may be employed.

Disadvantages :-

1. fuel loading is more elaborated and costly
2. power density is very low (9.7 K/litre). Therefore, a large size of vessel is required.

efficiency is low
coolant must be pressurised
5. Carbon dioxide dissociates above 300°c

LIQUID-METAL COOLED FAST BREEDER REACTOR (LMFBR)

The first experimental breeder reactor was a small plutonium-fueled mercury-cooled device operating at a power level of 25 kW. A breeder cooled with a mixture of sodium and potassium was placed in operation in 1951 at Argonne National Laboratory in Idaho. The Experimental Breeder Reactor - I (EBR-I) produced 200 kW of electricity is the world's first nuclear-generated electricity and it came from an LMFBR. Since they are early experiments, a considerable amount of LMFBRs has been constructed around the world.

Construction :-

All LMFBRs have two sodium loops :-
1. The primary reactor loop carries radioactive sodium, and
2. An intermediate sodium loop containing non-radioactive sodium carries the heat from the primary loop via an intermediate heat exchanger to the steam generator.

The detailed manner in which the intermediate sodium loop is arranged divides LMFBRs into two categories.
1. Loop-type LMFBR and
2. pool-type LMFBR

The loop-type appears on basis of simple concept except for the presence of the intermediate loop. It does not have much different in the design from an ordinary pressurized water reactor. It makes inspection, maintenance and repairs much easier than components which are immersed in hot radioactive and opaque sodium as they are in pool-type

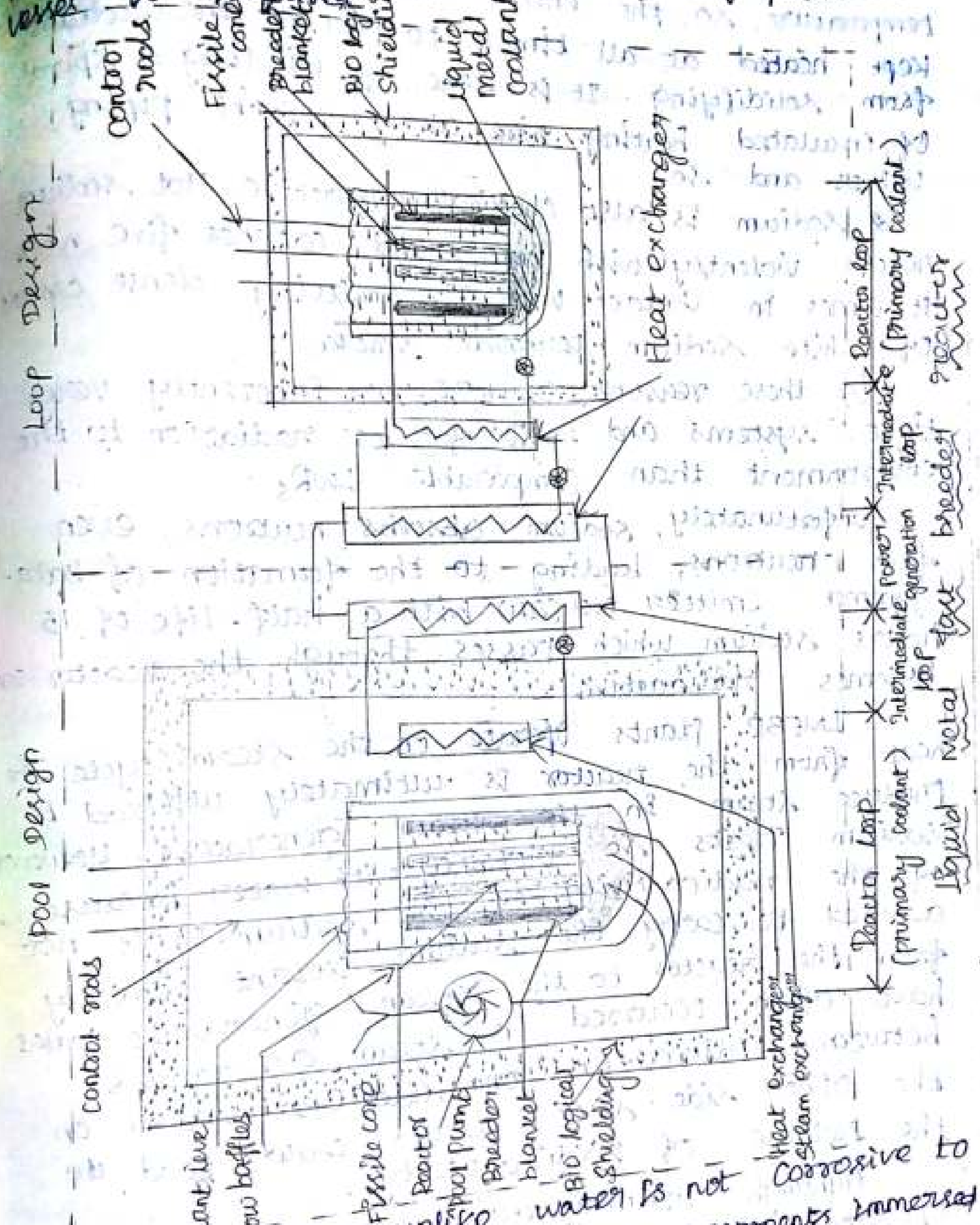
However, a substantial amount of shielding is required around all primary loops in a loop-type plant which makes these plants resemble Large and heavy built fortresses.

It contrast, a pool-type LMFBR has no radio-activity leaves the reactor vessel. so no other components of the plant must be shielded. In addition, the usual practice is to locate pool-type reactor vessels at least partially underground so that only the uppermost portion of the vessel requires heavy shielding. It is possible to walk into the reactor room where a pool-type reactor is operating and even walk across the top of the reactor without receiving a significant radiation does. Therefore, this type of LMFBR is very tight and compact.

Working principle :-

LMFBR operates on the Uranium - plutonium fuel cycle or thorium - U (233) fuel cycle. The reactor is fueled with breed isotopes of plutonium in the core and the blanket is natural or depleted uranium. The number of fission neutrons emitted per neutron absorbed by pu (239) increases monotonically with increasing neutron energy for energies about 100keV. Therefore, every effort must be made to prevent the fission neutrons in a fast reactor from slowing down which means that the lightweight nuclei must largely be excluded from the core. There is no moderator used in LMFBR. so. the core and blanket contain only fuel rods and coolant.

Sodium has universally been chosen as the coolant for the modern LMFBR. since sodium is an excellent heat transfer material, an LMFBR can be operated at high power density. This, in turn LMFBR core can be comparatively small. In addition, sodium has very high boiling high temperature and it can be operated at pressure without boiling essentially atmospheric; so no heavy pressure vessel is required.



Also sodium unlike water is not corrosive to many structural materials. Reactor components immersed in liquid sodium for years appear like new after the excess sodium has been washed off.

future.

Unit -4

POWER FROM RENEWABLE ENERGY

Introduction :-

84,000 MW hydroelectric power is at 60% load factor. In adding up. 6,780 MW in terms of installed capacity from small, mini and micro Hydel Schemes have been evaluated. Also, 56 sits for pumped storage schemes with the total installed capacity of 94,000 MW have been identified. Hydroelectric energy is mainly used in the form of renewable energy. India stands in 5th place for hydro-electric potential in the world on global scenario.

HYDROELECTRIC ENERGY RESOURCES :-

The present installed capacity as on September 30, 2013 was around 39,788.40 MW which means 17.39 % of total electricity generation in India. The public sector has a predominant share of 97% in this sector. National Hydroelectric power corporation (NHPC), Northeast Electric power company (NEEPCO), Satluj Jal Vidyut Nigam (SJVNL), THDC, NTPC-Hydro are few public sector. National Hydroelectric power companies developing hydro projects in India.

The purposes of developing hydro projects are mentioned below.

(i) To meet the power needs during peak and off-peak requirements.

(ii) To run of the river

(iii) To obtain a clean process of power generation

(iv) To avoid suffering from the limitation of inflation on account of fuel consumption in the long run.

In north India, Bhakra Beas Management Board (BBMB) has an installed capacity of 2.9 GW and it generates 12,000-14,000 million units per year. BBMB is a major source of peaking power and black start to the northern grid in India.

Hydro power :-

The turbine converts the hydraulic energy into mechanical energy. This mechanical energy is converted into electrical energy. So, the conversion of energy from hydraulic form into electric form, is called hydroelectric power.

Advantages of Hydro power :-

(i) The electricity can be produced at constant rate from hydro power.

(ii) If the electricity does not require, the sluice gates can be shut and stopped electricity generation.

(iii) The lake's water can be used for irrigation purposes.

(iv) The energy from stored water in the lake can be stored and it can be released to produce electricity.

Disadvantages of Hydro power :-

(i) Constructing the standard dams is highly expensive

(ii) The flooding area needs to be large to meet

(iii) It has the ... by natural calamity: for many decades restriction to operate the dam cost involved in building to become profitable due high dams.

(iv) People living in villages and towns near dams should be moved during flood period. So, the power generation will be affected.

(v) Although modern planning and design of dams is good, it may lead to deaths and flooding.

HYDEL POWER PLANTS :-

Water is the cheapest source of power. A hydro electric power plant is aimed at harnessing energy from water flowing under pressure. In hydroelectric power plants, the energy of water is utilized to drive the hydro turbine or waterpower is only important next to the thermal power. Hydroelectric power was initiated in India in 1897 near Darjeeling.

Hydrology is the study of science concentrating the properties of the earth's water and the movement of earth with respect to land.

A hydrograph is a graph plotted for the rate of flow versus time past a specific point in a river, or other channel or conduit carrying flow.

Classification of Hydro-Electric power plants according to the availability of head:-

(i) Classification

1. Low head power plant :-

The operating head of water is less than 10m of power plant known as low head power plant - Kaplan turbine is used as a prime mover in this type of power plant.

2. Medium head power plant :-

The operating heat of water ranges from 10m to 50 m, then the power plant is known as medium head power plant. Francis turbine is

3. High head power plant :-

If the operating head of water exceeds 50m the plant is known as "high head power plant". Pelton turbine is used as a prime mover in this type of power plant.

(ii) Classification according to the nature of load :-

1. Base load plant :-

This type of power plant is designed to take the load on the base portion of the load curve. The load on the plant is more or less constant throughout the operation period. Large scale hydro plants are used for this purpose.

2. Peak load plant :-

This type of powerplant is designed to take the load on the peak load of the load curve. The load on the plant is more or less constant throughout the opearation period. Small scale and micro-hydro plants are used for this purpose.

(iii) Classification according to the quantity of water available :-

1. Run-off river plant without pondage :-

This type of power plant has no storage pond. This type of power plant uses the water as it comes. This type of plant has no control over the river flow.

2. Run-off river plant with pondage :-

This type of power plant has a storage pond. This type of plant stores water during off peak hours and it is used during peak

... fluctuating load on 24 hours.

5. Storage type plants :-

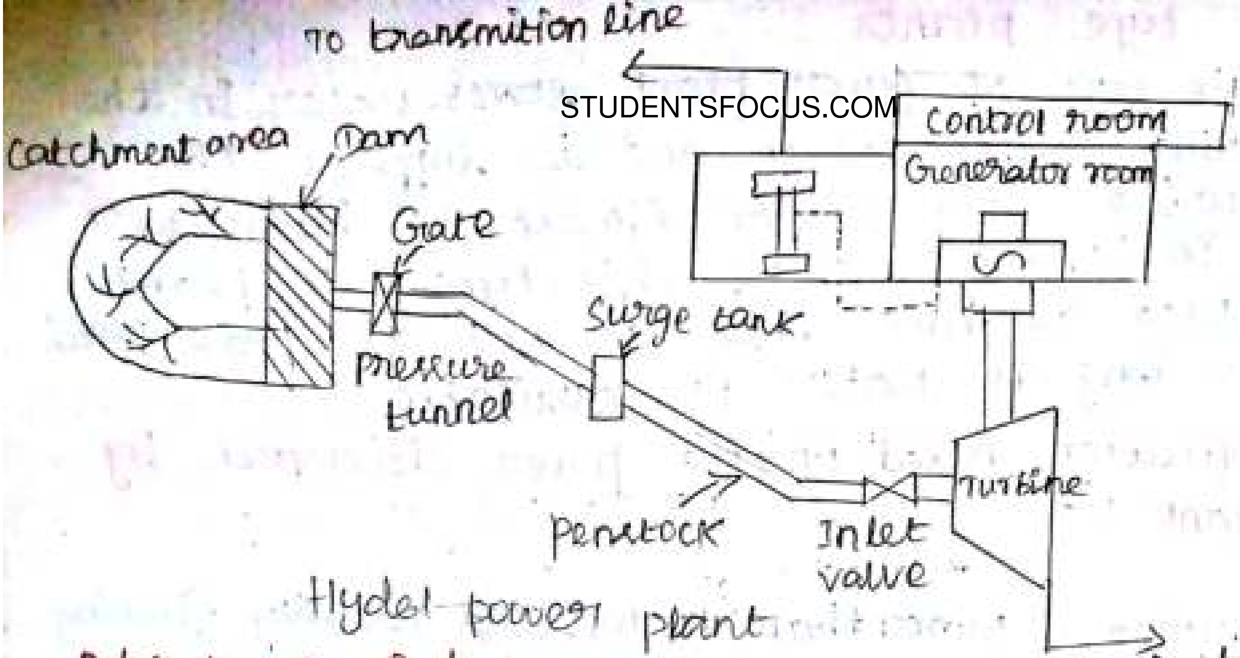
This type of power plant stores water in the dam during rainy season and it supplies the same during dry season. Almost all hydropower plants in India are of this type. This plant can be used as base load as well as peak load plant as long as water is available.

(iv) classification based on the power developed by the plant :-

Large-hydro	More than 100MW and usually feeding into a large electricity grid.
Medium-hydro	15-100 MW - usually feeding a grid
small-hydro	1-15 MW - usually feeding into a grid
Mini-hydro	Above 100KW but below 1MW - either stand alone schemes or more often feeding into the grid.
Micro-hydro	from 5KW up to 100KW, usually provided power for a small community or rural Industry in remote areas away from the grid.
pico-hydro	from a few hundred watts up to 5KW

Working principle of Hydel power plant or low Head Hydel power plant :-

In hydroelectric power plants, the potential energy of water is converted into kinetic energy. The potential energy of water is used to run the water turbine to which the electric generator is coupled. The mechanical energy available at the shaft of the turbine is converted into electrical energy through a generator or alternator. The water is first passed through the penstock to the turbine from the dam.



Hydel power plant

Advantages of hydroelectric power plant :-

1. water is the cheapest source of energy. The fuels needed for the thermal, diesel and nuclear plants are exhaustive and expansive.

2. water is the renewable source of energy. It is neither consumed nor converted into something else

3. The fuel cost is totally absent.

4. There is no problem of handling the fuel and ash. No nuisances of smoker exhaust gases and soot's and no health hazards are due to air pollution.

5. The running cost of hydropower Installation is low when compared to thermal or nuclear power stations

6. The efficiency does not change with age

7. Maintenance cost is low.

Disadvantages of hydroelectric power plant :-

1. Hydropower projects are Capital-Intensive with a low rate of return.

2. power generation is dependent on the quantity of water available which may vary season-to-season and year-to-year.

3. Initial cost of the plant is high

4. The hydel power plants are often far away from the load Center and they require long transmission lines to deliver power.

Large hydro-plants disturb the ecology of the area by way of deforestation, destroying vegetation and uprooting people.

Water Turbines :-

Hydraulic turbines are the machines which convert flowing energy of water into mechanical energy. The mechanical energy developed by a Turbine is used to run an electric generator which is directly coupled to the shaft of the turbine. Thus the mechanical energy is converted into electrical energy.

Hydraulic turbines may be classified according to several considerations as follows.

i) According to the action of the water flowing :-
a. Impulse turbine e.g:- pelton wheel
b. Reaction turbine e.g:- francis turbine, kaplan-turbine

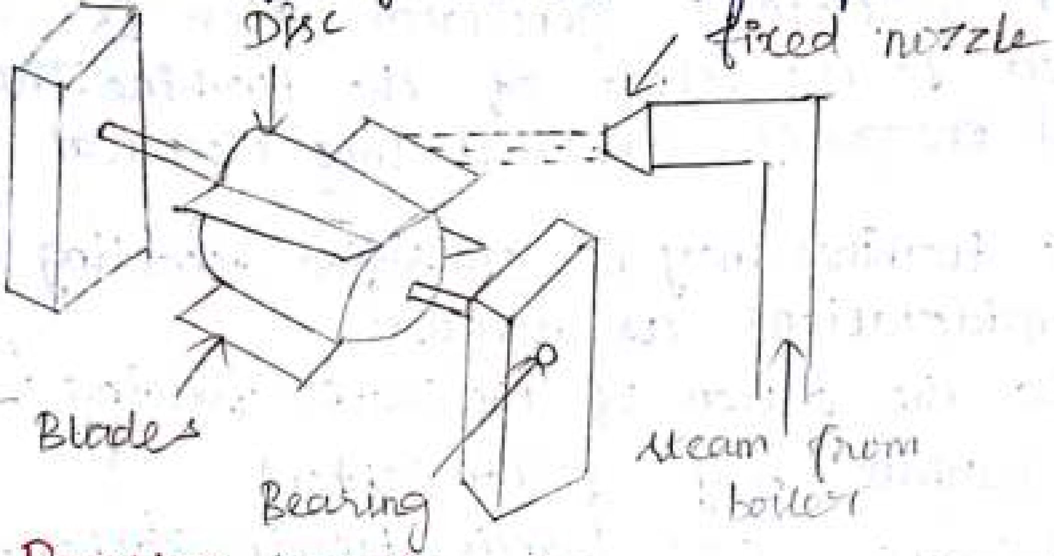
ii) According to the main direction of flow of water :-
a. Tangential flow turbine e.g:- pelton wheel
b. Radial flow turbine e.g:- old francis turbine
c. Axial flow turbine e.g:- Kaplan turbine
d. Mixed flow turbine e.g:- Modern francis turbine

iii) According to the head and quantity of water required
a. High head turbine (above 250m) e.g - pelton wheel
b. Medium head turbine (60m to 250m) e.g:- Modern francis turbine
c. Low head turbine (Less than 60m) e.g kaplan turbine

iv) According to the specific speed
a. low specific speed (10 to 35) e.g:- pelton wheel
b. Medium specific speed (60 to 400) e.g francis turbine
c. High specific speed (300 to 1000) e.g:- kaplan turbine

Impulse Turbine :-

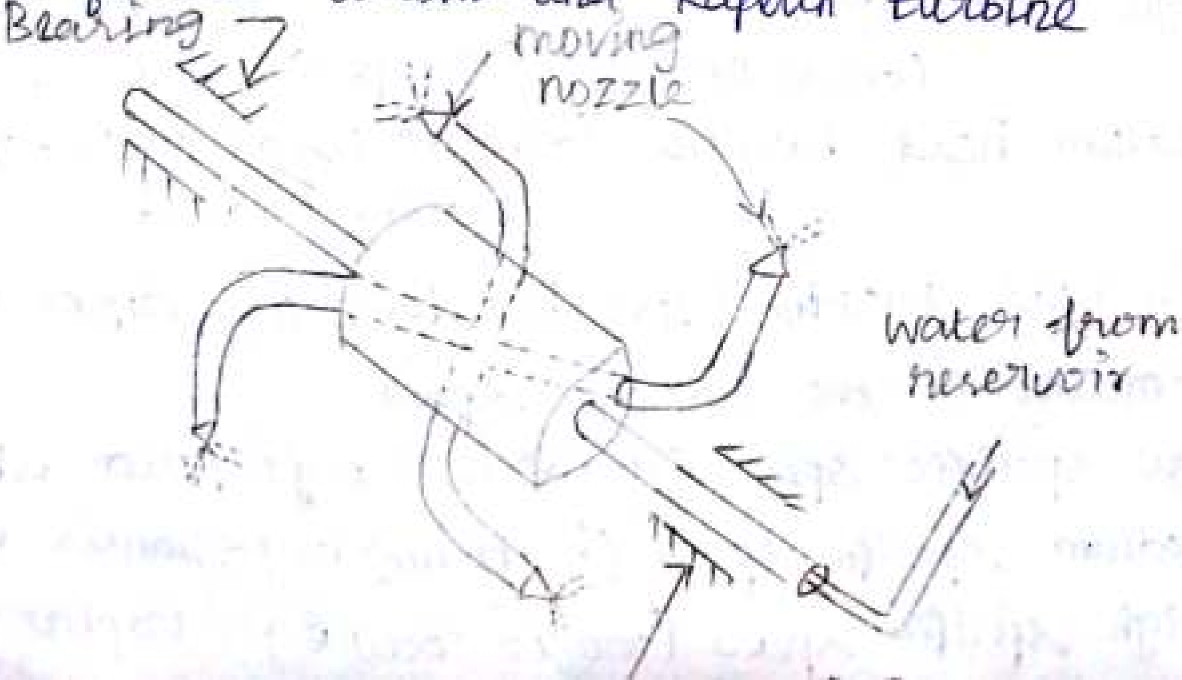
In an Impulse turbine the energy available by water is converted into kinectic energy by passing it through a nozzle. The high velocity jet coming out of the nozzle Impinges on a series of buckets fixed around the rim of a wheel. Thus, the runner revolves freely in air Eg:- pelton wheel.



Reaction Turbine :-

In a reaction turbine, the runner utilizes both potential and kinetic energies. Here, only a portion of potential energy is transformed into kinectic energy before the fluid enters the turbine runner. As the water flows through the runner, the remaining part of potential energy is converted into kinectic energy.

Eg:- francies turbine and kaplan turbine



In tangential flow turbines water flows along the tangent to the path of the runner. Eg :- pelton wheel.

Radial flow Turbine :-

In radial flow turbines, water flows in the radial direction and mainly in the plane normal to the axis of rotation as it passes through the runner. It may be either inward radial flow type or outward radial flow type.

Axial flow Turbine :-

In an axial flow turbine, water flows parallel to the axis of the turbine shaft. Eg :- Kaplan turbine and propeller turbine.

Mixed flow Turbine :

In mixed flow turbines, the water enters the blades radially and it comes out axially or parallel to the turbine shaft. Eg :- Modern francis turbine

Wind Energy conversion :-

Principle of Wind Energy conversion

The wind energy can be extracted from lift force alone or drag force alone or combination of lift and drag forces. It is known that the lift force acts perpendicular to the air flow direction and drag force acts parallel to the wind direction. The lift is produced by the change in velocity of air stream which speeds up the air flow thereby creating a pressure drop. So, the pressure drop forces the lift surface from high pressure side to low pressure side called an airfoil. If the air pressure increases on the low pressure side, enormous turbulence is produced which reduces the lift force and it leads to increase the drag significantly called stalling.

The basic features which characterize lift and drag are as follows :

(1) Drag is in the direction of airflow

(2) ... is perpendicular to the direction of airflow

(iii) Generation of lift always ... amount of drag to be developed with a good aerofoil.

(iv) The lift produced can be thirty times greater than the drag.

(v) Lift devices are generally more efficient than drag devices.

TIDAL ENERGY :-

The periodic rise and fall of the water level of sea which are carried by the action of sun and moon on water of the earth is called "Tide". The difference in potential energy during high-tide and during low-tide is called Tidal Energy.

The main feature of the tidal cycle is the difference in water surface elevations at high tide and low tide. If this differential head could be utilized in operating a hydraulic turbine, the tidal energy could be converted into electrical energy by means of an attached generator.

Tidal energy can furnish a significant portion of all such energies which are renewable in nature. Tidal energy is a form of hydro energy recurring with every tide.

Spring tides :-

If the tide's range is maximum, this is called the spring tide. Around new and full moon days when the sun, Moon and Earth form a line. The tidal force due to the sun reinforces the Moon.

Neap tides :-

When the moon is at first quarter or third quarter, the sun and Moon are separated by 90° when viewed from the Earth and the solar gravitational force partially cancels the moon's. At these points in the lunar cycle, the tide's ... minimum called neap tide.

...Schemes and Configurations :-

There is much interest in the use of tidal energy especially the development of large scale tidal power schemes. The power is obtained through the flow of water when filling and emptying partially closed sea basins. A proposed scheme exists for the Bristol Channel (UK). As the tide runs into the 'low' basin, it drives turbines and as the tide retreats, again turbines are turned to produce large amounts of electricity. Unfortunately this scheme has been shelved due to cost and possible damage to the local ecology.

Tidal energy could satisfy as much as 5% of UK's electricity needs but depending on how it is implemented, such a scheme could also cause severe damage to wildlife in the area including birds, shore-life, and fish and plants that thrive in the delicate ecosystem.

Martin Harper, head of sustainable development at RSPB said, "The government does not need to rush to judgment on it. If they do, there is a serious risk they will pick the wrong project. As this review shows that it could mean unnecessary damage to the environment, an oversized bill for the taxpayer and all for less electricity than is possible."

Impact of Tidal Energy on the Environment :-

(i) Tidal energy is a renewable source of electricity which does not cause the emission of gases responsible for global warming or acid rain associated with fossil fuel generated electricity.

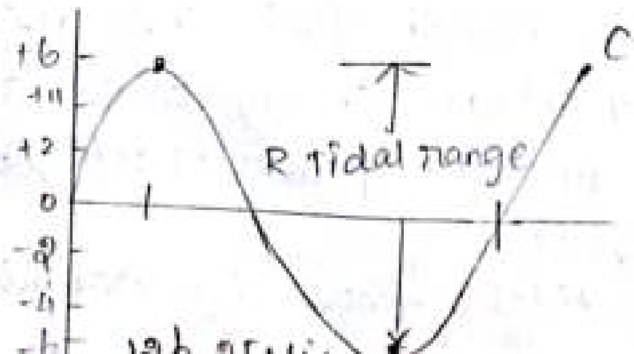
(ii) The use of tidal energy could also decrease the need for nuclear power with its associated radiation risks.

(iii) Changing tidal flows by damming a bay or estuary could result the negative impacts on aquatic and [illegible] ecosystems as well as navigation and recreation.

Principle of Tidal power :-

Mainly, tides are produced by gravitational attraction of the Moon and sun on the water of solid earth. Nearly, 70% of the tide produces force due to Moon and remaining 30% by the sun. So, the Moon is the main factor to form tides in the sea. During the tide formation, the surface water is pulled away from earth towards Moon but at the same time, the solid earth is pulled away from the water on the opposite side. Therefore, high tides form in these two areas and low tides are formed at intermediate points. Due to the rotation of earth, the position of the solid area changes relative to Moon thereby forming tides. Thus, a periodic succession of high and low tides is formed.

Two high tides and two low tides occur in a lunar day of 24 hours and 50 Minutes. The lunar day is the apparent day of moon revolution about the earth. The time delay between successive tides is 6 hours. High tide occurs at a point directly under the Moon. Therefore, high tides are produced during full Moon and no Moon day of the mouth. These tides are called as semi-diurnal tides. So, the rise and fall of sea water is in sinusoidal wave forms.



$C_xH_yO_z + (x - \frac{y}{4} - \frac{z}{2}) H_2O \rightarrow (\frac{x}{2} - \frac{y}{8} + \frac{z}{4}) CO_2 + (\frac{x}{2} + \frac{y}{8} - \frac{z}{4}) ...$

For cellulose, the equation becomes

$$(C_6H_{10}O_5)_n + nH_2O \rightarrow 3nCO_2 + 3nCH_4$$

In general 95% of the mass of the material is water. The reactions are slightly exothermic with typical heats of reaction being about 1.5 MJ/kg dry digestible materials equal to 250 kJ/mole of $C_6H_{10}O_5$. If the input material is dried and burnt, the heat of combustion is about 16 MJ/kg only 10% of the potential heat of combustion required for the digestion process. It produces 90% conversion efficiency. Digestion at higher temperature proceeds more rapidly than lower temperature with doubling gas yield rate at about every 5°C increase.

1. Psicrophilic (20°C)
2. Mesophilic (35°C)
3. Thermophilic (55°C)

The biochemical processes occur in three stages and each is facilitated by distinct sets of anaerobic bacteria.

Insoluble biodegradable materials :-

It occurs in about a day at 25°C in an active digester.

Acid forming bacteria produce mainly acetic and propionic acid :-

This is about one day at 25°C

Methane forming bacteria :-

Bacteria needs 14 days at 25°C to complete the digestion to 70% CH_4, 30% CO_2 with less amount of H_2 and H_2S.

Fuel Cell :-

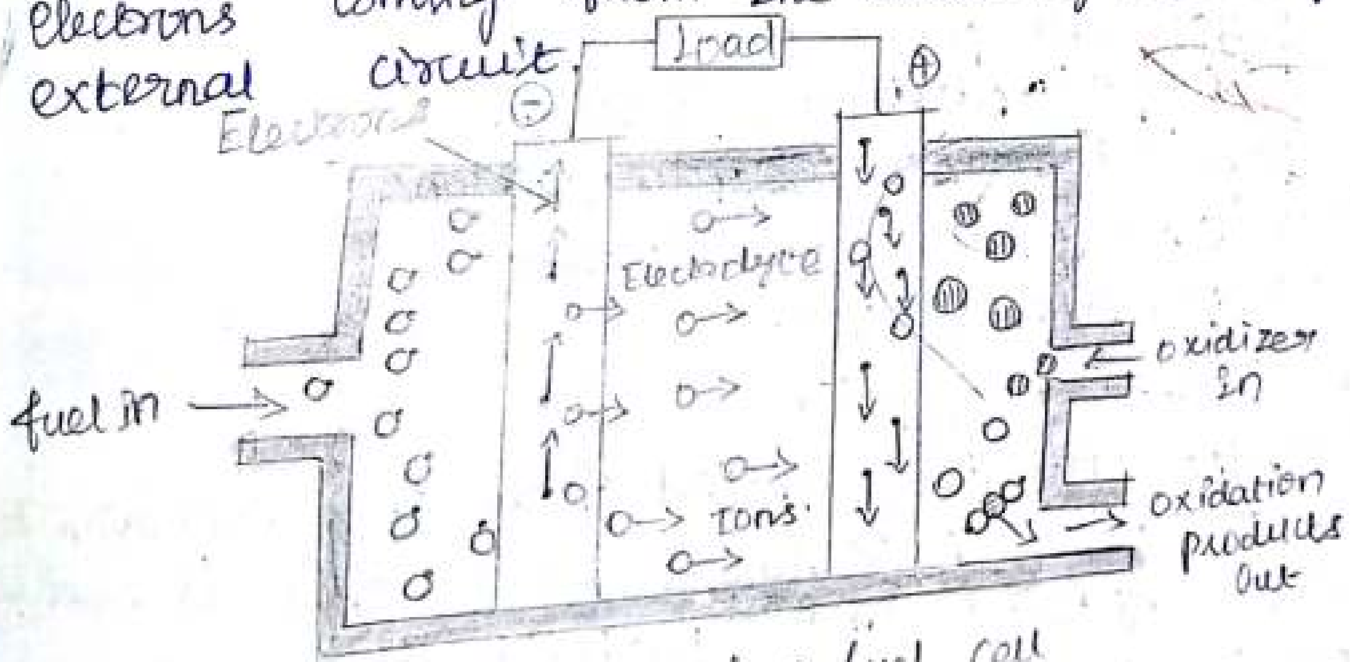
Fuel cell technology is over 150 years old. The first fuel cell was demonstrated by Sir William Groove in 1839. Groove used porous electrolyte bath - William White Jaques later Substituted phosphoric acid in the electrolyte bath and was the person who Coined the term "fuel cell"

A significant fuel cell research was done in Germany during 1920's. which laid the ground work for subsequent development of carbonate cycle and solid oxide fuel cells. In 1960S, NASA

Working Principle of a fuel cell :-

A fuel cell is an electrochemical device in which the chemical energy of a conventional fuel is directly converted and efficiently into low voltage DC electrical energy. One of the main advantages of such a device is that the carnot limitation on efficiency does not apply because the conversion can be carried out isothermally. A fuel cell is frequently described as a primary battery in which the fuel and oxidizer are stored in the battery and fed to it as needed.

Therefore, it releases electrons to the external circuit. The oxidized fuel diffuses through the cathode and it is reduced by electrons coming from the anode by the way of external circuit.



Schematic of a fuel cell

The fuel cell is a device which keeps from mixing with the oxidizer molecules

molecules in permitting the transfer of electron by a metallic path that may contain a load of the

available fuels. Hydrogen has so far given the most promising results; although cells consuming coal, oil or natural gas would be economically much more useful for large scale applications.

Some of the possible reactions are.

Hydrogen / oxygen 1.23 V $2H_2 + O_2 \Rightarrow 2H_2O$

Hydrazine 1.56 V $N_2H_4 + O \Rightarrow 2H_2O + N_2$

Carbon (coal) 1.02 V $C + O_2 \Rightarrow CO_2$

Methane 1.05 V $CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O$

A fuel cell power system has many components but its heart is the fuel cell stack which is made of many thin, flat cells layered together. Each cell produces electricity and the output of all cells is combined to get more power.

Major sections of fuel cell power plants :-

The fuel cell power plant consists of six major sections which are as follows.

(i) fuel processing section
(ii) fuel cell power pack
(iii) power conditioning section
(iv) switchgear and supply section
(v) control subsystem section
(vi) Heating section.

fuel processing section :-

The fuel is supplied from this section to fuel cell power pack. The supplied fuel is received, processed, filtered and purified.

fuel cell power pack section :-

The processed fuel is sent to the fuel cell power pack along with air or oxidant which is

... in the other system. The fuel cell produces DC power in this section and it is sent to power conditioner.

Power Conditioning section :-

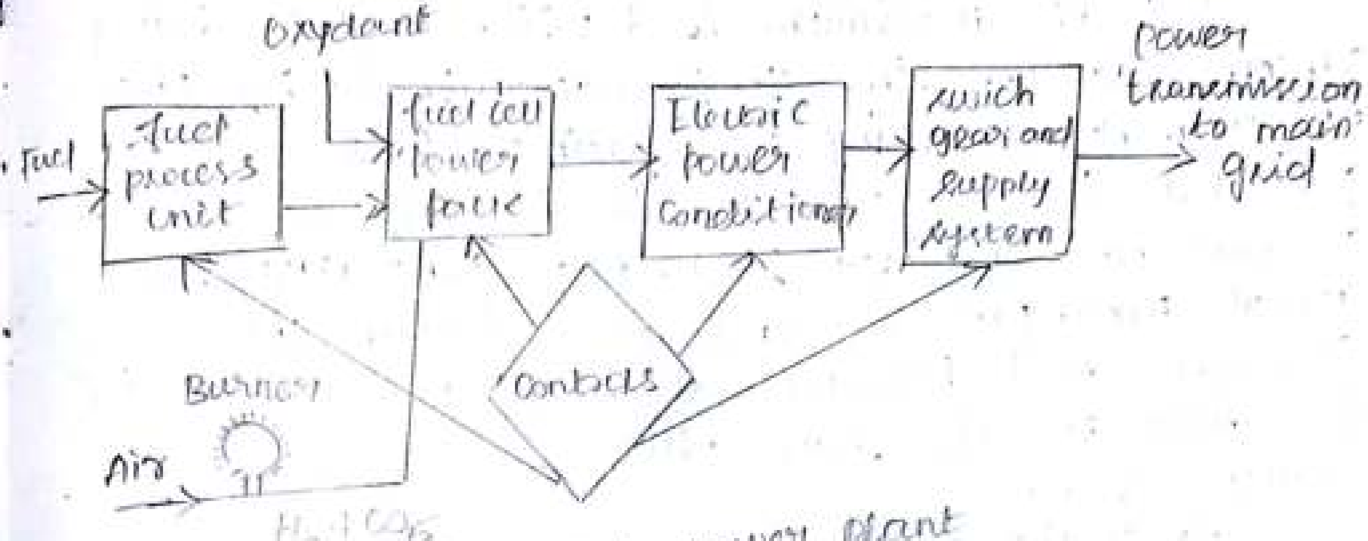
DC power coming out of fuel cell power pack is converted into 3 phase or single phase regulated AC power.

Switchgear and supply section :-

This section delivers AC power to the connected load.

Control subsystem section :-

This section controls the voltage, current, power, rate of power, fuel input and temperature.



fuel cell power plant

Heating section :-

The working temperature of electrolyte is maintained within the permissible limit in this section by installing a heating subsystem.

Unit-5

ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS

Introduction :-

Economics of power plant

Important Terms and Definitions :-

Connected load :-

It is the combined continuous rating of all receiving apparatus on consumer's premises. If a consumer has connections for 3 lamps of 40 W each and power point of 500 W for refrigerator and TV consuming 60 W, then the total connected load of the consumer $= 3 \times 40 + 500 + 60 = 680$ W.

Demand :-

It is the load which is drawn from the source of supply at the receiving terminals averaged over a suitable and specified interval of time.

Maximum demand :-

It is the maximum load which is used by a consumer at any time. It is determined by the measurement according to specifications over a prescribed interval of time. It can be less than or equal to connected load. But generally, the actual maximum demand is less than the connected load because all loads never run in full load at the same time.

Demand factor :-

It is the ratio of actual maximum demand of the system to the total connected demand of the system.

$$\text{Demand factor} = \frac{\text{Actual maximum demand}}{\text{Total connect demand}}$$

Load factor :-

It is the ratio of the average load over a given time interval to the peak load during the same time interval

$$\text{Load factor} = \frac{\text{Average load over a given time interval}}{\text{peak load during the same time}}$$

... less than unity.

Capacity factor or plant capacity factor:

It is the ratio of actual energy produced in Kilowatt hours (kWh) to the maximum possible energy which could have been produced during the same period.

$$\text{Capacity factor} = \frac{\text{Actual energy produced in kWhr}}{\text{Rated capacity of the plant}} = \frac{E}{C \times t}$$

$$\text{Capacity factor} = \frac{\text{Average load}}{\text{Rated capacity of the plant}}$$

where $E \Rightarrow$ Energy produced in kWh

$C \Rightarrow$ Capacity of the plant in kW

$t \Rightarrow$ Total numbers of hours in given period.

The load factor and capacity of the plant is factor will be numerically equal.

Utilization factor:-

It is the ratio of maximum load to the rated capacity of the plant

$$\text{Utilization factor} = \frac{\text{Maximum load}}{\text{Rated capacity of the plant}}.$$

Reserve factor:-

It is the ratio of load factor to the capacity factor.

$$\text{Reserve factor} = \frac{\text{Load factor}}{\text{Capacity factor}}$$

Dump power:-

This term is used in hydroelectric power plants. It shows the power in excess of the load requirements.

Prime power:-

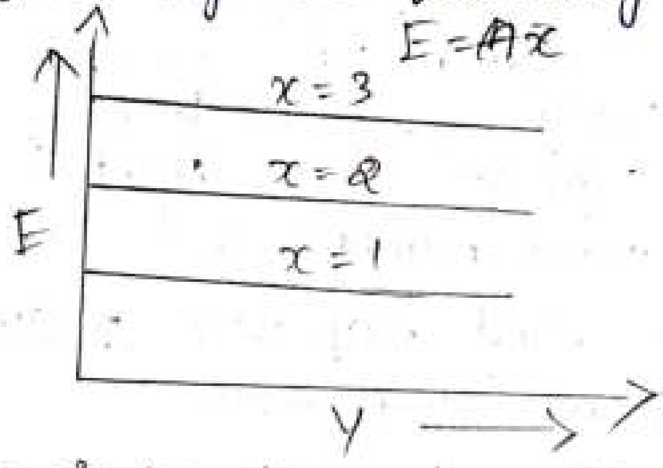
The power may be mechanical power, Hydraulic power or thermal power which is always available for the conversion into

The various forms used for charging consumers as per their energy consumed and Maximum demand are discussed below.

Flat Demand Rate :

In this type of charging, the charging depends only on the connected load and fixed number of hours of use per month or year. It can be given by the following equation.

$E = Ax$

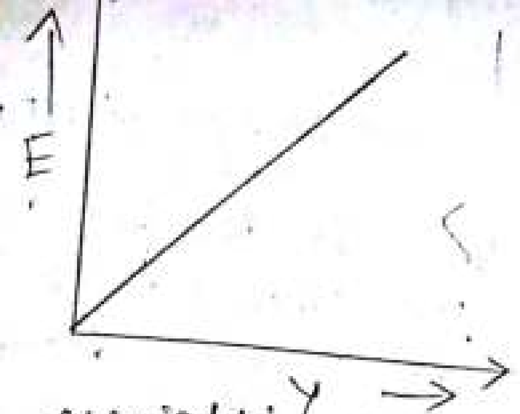


flat demand rate

As per the above discussions, the notations are taken. This rate expresses the charge per unit of demand (kW) of the consumer. Here, no metering equipment and manpower are required for charging. In this system, the consumer can theoretically use any amount of energy consumed by all connected loads. The unit energy cost decreases progressively with an increased energy usage. The variation in total cost and unit cost.

Straight line Meter Rate :-

This type of charging depends on the amount of total energy consumed by the consumer. The bill charge is directly proportional to the energy consumed by the consumer. It can be represented by the following equation.



straight meter rate

The major drawbacks of this system are as follows.

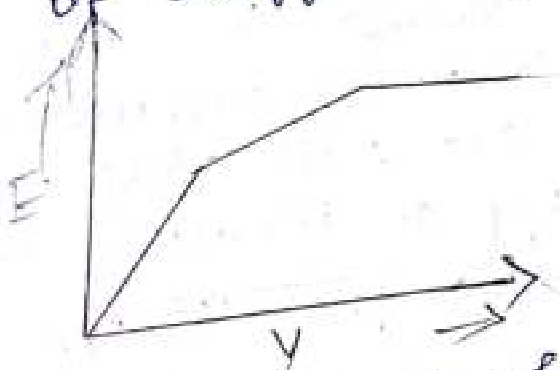
a) In this type of system, the consumer using no energy will not pay any amount although he/she incurred some expenses to the power station.

b) The rate of energy is fixed. Therefore, this method of charging does not encourage the consumer to use more power.

The variation in total cost and unit consumed.

Block - Meter Rate

In previous straight line meter rate, the unit charge is same for all magnitudes of energy consumption. The increased consumption spreads the item of fixed charge over a greater number of units of energy.



Therefore, the price of energy should reduce with increase in energy consumption. The block meter rate is used to overcome this difficulty. This method of charging is by the equation.

$E = B_1Y_1 + B_2Y_2 + \ldots$

where $B_3 < B_2 < B_1$ and

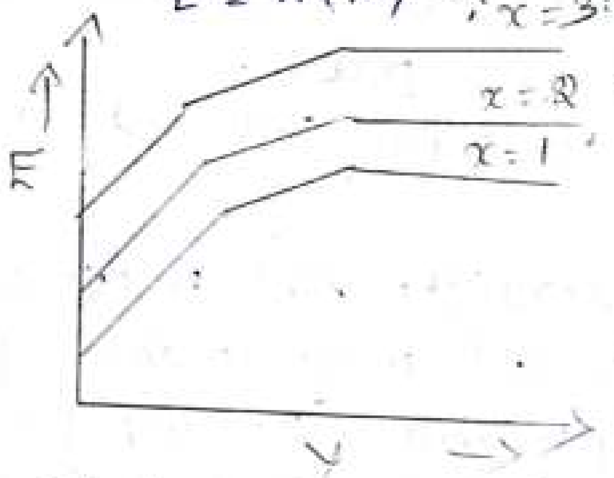
$Y_1 + Y_2 + Y_3 + \ldots = Y$ (total energy consumption)

The level of $Y_1, Y_2, Y_3 \ldots$ is decided by the government to recover the capital cost. In this system, the rate of unit charge decreases with increase in consumption of energy.

Hopkinson Demand Rate of Two-part Tariff:-

This method of charging depends on the maximum demand and energy consumption. This method is proposed by Dr. John Hopkinson in 1982. This method of charging is represented by the equation

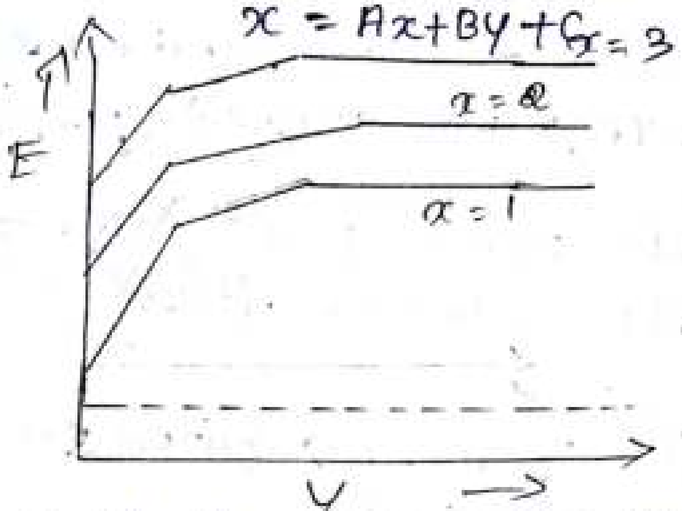
$$E = A + BY$$



In this method, two meters are required to record the maximum demand and energy consumption of the consumer. This method is generally used for industrial consumers. The variation in total cost with respect to the total energy consumption taking x, as parameter.

Doherty Rate or Three part Tariff :-

This method is proposed by Henry L. Doherty. In this method of charging, the consumer has to pay some fixed amount in addition to charges for maximum demand and energy depends on the occasional increase in prices and wage charges of the workers etc. This method of charging is expressed by the equation



This method of charging is most commonly used in tamilnadu and all over India. In this method, the customers are discouraged to use more power when the generating capacity is less than actual demand. for examples, for the first 50 KWh units, the charging rate is fixed says Rs 2.5/KWh and if it exceeds this charge, it is rapidly increased as Rs 3.5/KWh for next 100 KWh unit. (ie) from 51 KWh to 150 KWh) this method is unfair to the customer but it is very common in India and many developing nations.

LOAD DISTRIBUTION PARAMETERS

The loads are distributed in many ways. The various type of loads are described below.

Residential load :-

This type of load includes domestic lights and power needed for domestic appliances such as radios, television, electric cookers, water heaters, refrigerators, grinders etc.

commercial load

It includes lighting for shops, advertisements and electric appliances used in shops, hotels restaurant etc

Industrial load :-

It consists of load demand of various Industry

Municipal load :-

It consists of power required for street lights, water supply and drainage purposes.

Irridation load :-

It includes electrical power required for pumps to supply water to fields.

Traction load :-

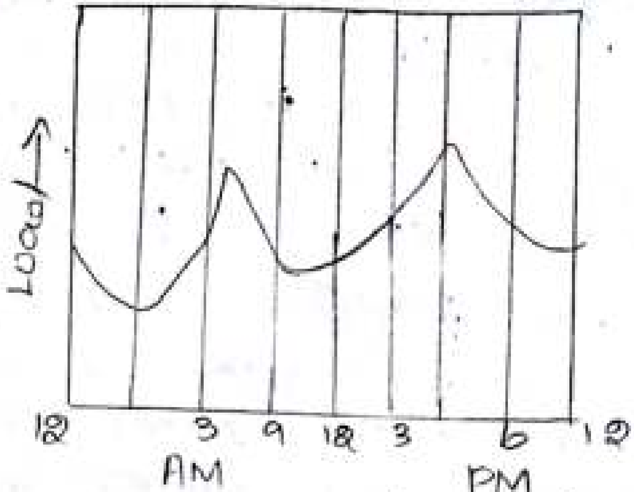
It consists of power required for tram cars, trolley, buses and railways.

LOAD CURVE :-

It is a graphical representation which shows power demands for every instant during a certain time period. It is drawn between load in KW and time in hours. If it is plotted for 1 hour it is called hourly load curve and if the time is considered is of 24 hours, then it is called daily load curve. When it is plotted for one year (8760 hours) then it is called animal load curve.

The area under the load curve represents the energy generated in the period considered. If the area under the curve is divided by the total number of hours, then it will give the average load on the power station. The peak load indicated by the load curve represents the maximum demand of the power station.

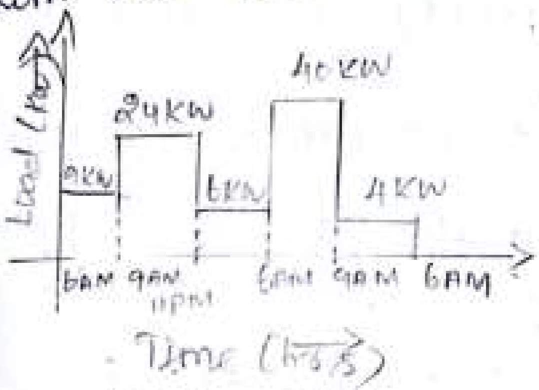
This curve gives full information about the incoming loads and it helps to decide the installed capacity of the power station. It is also useful to decide the economical size of various generating units.



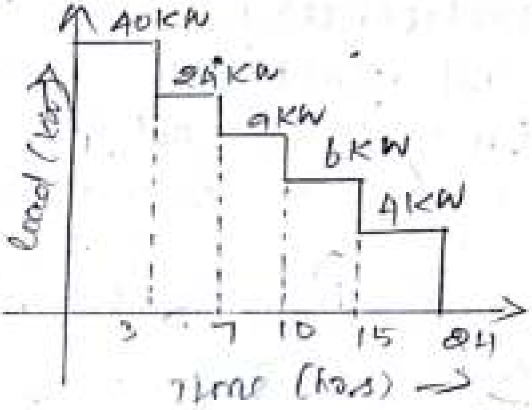
Load curve

LOAD DURATION CURVE :-

This curve represents the re-arrangement of all load elements of load curve in order to decreases its magnitude. This curve is derived from the load curve.



Load curve



Load duration curve

A typical daily load curve for a power station. The maximum load on power station is 40 KW from 6p.M to 9 P.M. similarly, other loads of the load curve are plotted in decreasing order. This curve is called, load duration curve.

The area under both curves is equal and it represents the total energy delivered by generation station. Load duration curve gives a clear analysis about generating power economically.

Load distribution parameters, :-

comparison of site selection criteria :-

Changing the site and variability still increases the cost of power plants. It is due to different locations needed ... for the use of Union or non-Union labor. Over all productivity and labor cost vary in different regions. Sales tax rates vary and local market conditions also vary. Even profit margins and perceived risk can vary.

Site-specific scope is also an issue. Access roads, lay down areas, transportation distances to the site and availability of utilities, Indoor vs. outdoor buildings, ambient temperatures and many other site-specific issues can effect the scope and specific equipment need choices.

The site selection criteria of various plants such as thermal or steam, nuclear, gas turbine, diesel, hydroelectric, solar, geothermal, tidal, wind, biogas and fuel cell are already discussed in from Unit 1 to Unit 4

RELATIVE MERITS AND DEMERITS OF VARIOUS POWER PLANTS :-

Relative merits and demerits of various plants are already discussed in from unit 1 to unit 4

CAPITAL COST AND OPERATING COST OF VARIOUS POWER PLANTS :-

Both capital cost and operating cost are always based on the technique and availability of resources used for energy generation. Based on above-mentioned procedure for the calculation of energy generation cost, various energy research laboratories release the report about the cost of energy generation such as National Renewable energy laboratory (NREL), Energy and Environmental Energy Policy Resources (EEPR), science, and Industry Division (SID) by congressional research service, US energy information administration and world energy council, some examples.

Capital cost and Operating cost of Nuclear and Gas turbine power plants :-

The cost of nuclear power plants are given for producing 1125 MW but it is 211 MW for gas turbine power plant. Even cost is estimated for future energy generation also. The report describes the cost for the year up to 2050. In tables below, CC refers the Capital cost and OC refers the operating cost.

Year	Nuclear power plant		Gas turbine power plant	
	CC (Dollar/KW)	OC (Dollar/KW year)	CC (Dollar/KW)	OC (Dollar/MWh)
2008	6,230	----	671	----
2010	6,100	127	651	29.9
2015	6,100	127	651	29.9
2020	6,100	127	651	29.9
2025	6,100	127	651	29.9
2030	6,100	127	651	29.9
2035	6,100	127	651	29.9
2040	6,100	127	651	29.9
2045	6,100	127	651	29.9
2050	6,100	127		

POLLUTION CONTROL TECHNOLOGIES INCLUDING WASTE DISPOSAL OPTIONS FOR COAL

Analysis of pollution from Thermal power plants :-

The demand for electric power is continuously increasing. The power plants are simultaneously facing the problem of impurities and pollution in atmosphere. The main pollutants from the thermal plants are dust and objectionable gases CO_2, SO_2, NO_2 and ash

The pollution from the thermal plant is the discharge of large quantity of heat to the atmospheric air and the water is used for condensing the steam.

Air and water pollution by Thermal power plants:

Air pollution in the environment causes lung cancer. The environmental pollution by thermal power plants using fuels causes a serious health hazard. A 350MW coal fired thermal power station emits about 75 tons of SO_2, 16 tons of nitrogen oxide and 500 tons of ash per day. All steam plants discharge 60%. of heat to the atmosphere.

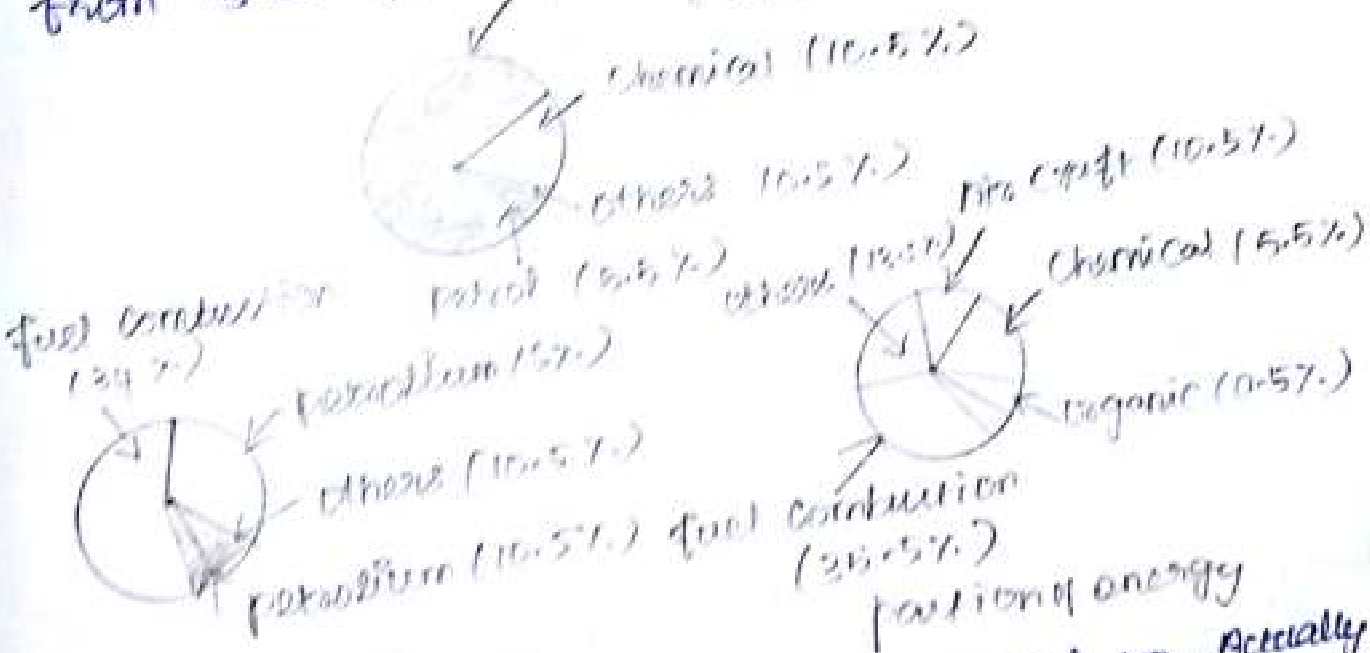
CO emission due to incomplete combustion of fuel in furnaces causes human health and it combines with homoglobin in red blood corpuscles.

CO_2 emission due to combustion of fuel will affect atmospheric climate which could turn fertile land into deserts. SO_2 emission in the steam power plant will cause the toxic effect vegetables are most sensitive to the contact of SO_2 gas in the atmosphere. It is the main pollutant from steam power plants.

Another emission of nitric oxide will not affect the atmosphere. But, NO_2 is a result of series of chain reactions highly irritant to the lung. The maximum permissible limit of nitrogen oxide is 0.05 to 0.1 ppm. Exposing 2 to 3 ppm of nitrogen oxide for a couple of hours causes fibrotic changes in pulmonary tissues. The table describes the pollutants emitted by 400 MW plant for different fossil fuels.

	Annual emission in, of a plant using ... (of ...%)		
	Coal	Oil	Natural gas
Fuel used annually	[illegible] tons (3.5% sulphur and 9% ash)	[illegible] (1.6% sulphur content)	[illegible]
Pollutants Aldehydes	4.6×10^{4}	$1.03\times10^{[illegible]}$	8.18×10^{4}
Oxides of nitrogen	1.24×10^{7}	1.91×10^{7}	1.06×10^{7}
Oxides of sulphur	$1.38\times10^{[illegible]}$	1.61×10^{7}	1.02×10^{7}
Carbon monoxide	4.6×10^{5}	1.36×10^{3}	negligible
Hydrocarbons	1.24×10^{5}	5.22×10^{5}	negligible
Particulates	$3.96\times10^{[illegible]}$	6.4×10^{5}	1.62×10^{3}

A 400 MW plant emits 800 tons of fly ash per day and the ash content of coal in India varies from 3 to 42 %

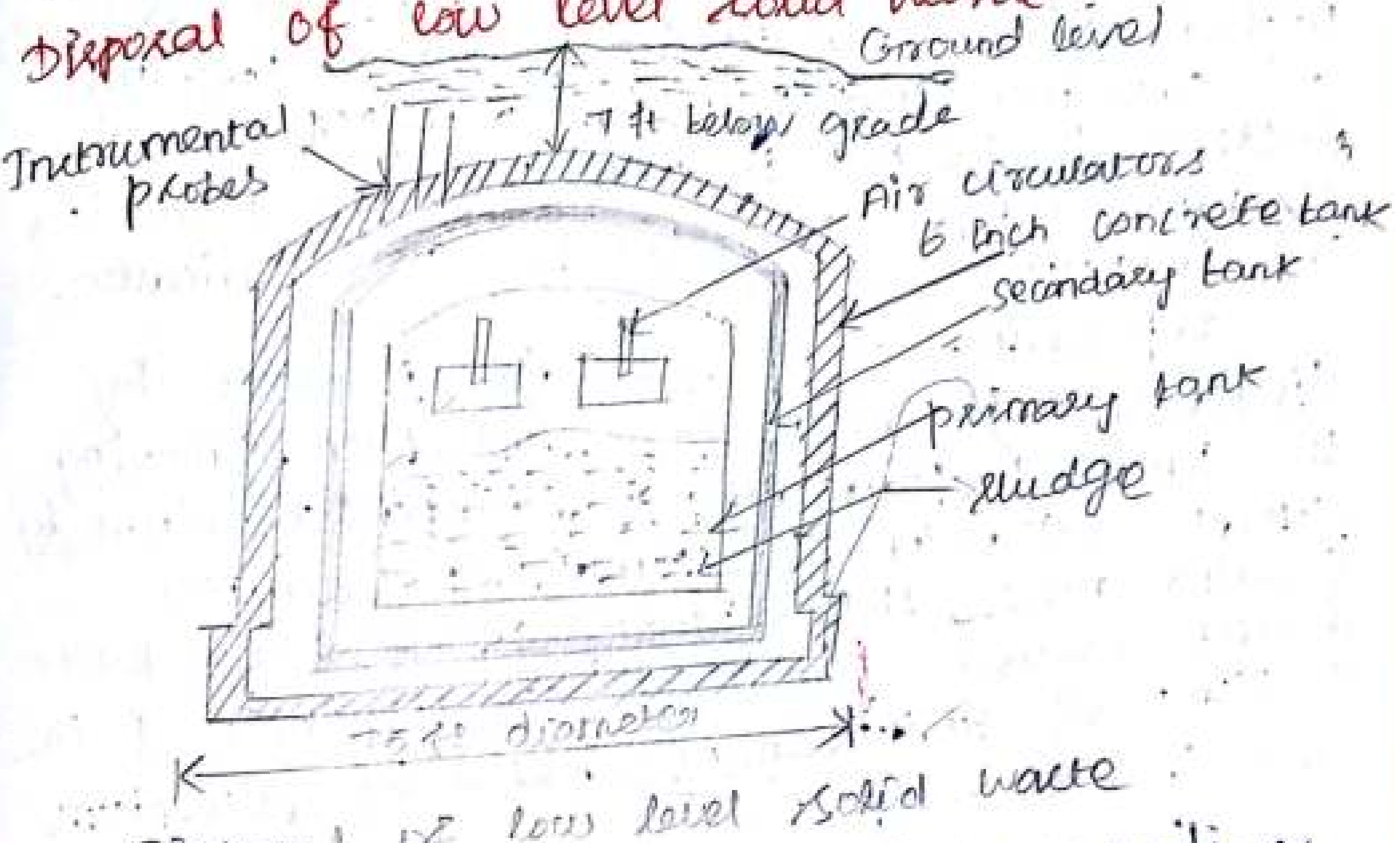


portion of energy

The contribution of SO_2 and NO_x. Actually the air constitutes about 80% of man's daily intake by weight. We breathe about 22000 times a day inhaling about 16 kg of air. The effects and medium level wastes are buried at a depth of few meters at carefully selected sites.

Gaseous wastes are discharged to the atmosphere through high stacks. Liquids having low or medium level of radioactivity are given preliminary treatment to remove the most of activity in the form of solid precipitate and then it is discharged in dry wells or deep pits. Different methods for various nuclear wastes disposed are discussed below.

Disposal of low level solid waste



Disposal of low level solid waste

Low level solid waste requires little or no shielding. It is usually disposed off by keeping it in a steel or concrete tank. These tanks are buried either few meters below the soil or kept at the bed of the ocean.

Disposal of medium level solid wastes :-

Medium level wastes are mainly contaminated with neutron activation products ... they are incorporated into cement cylinders. Cement is non-combustible material and it provides shielding against the external exposure. Cement is also having the ability of resistance to reach by ground water.

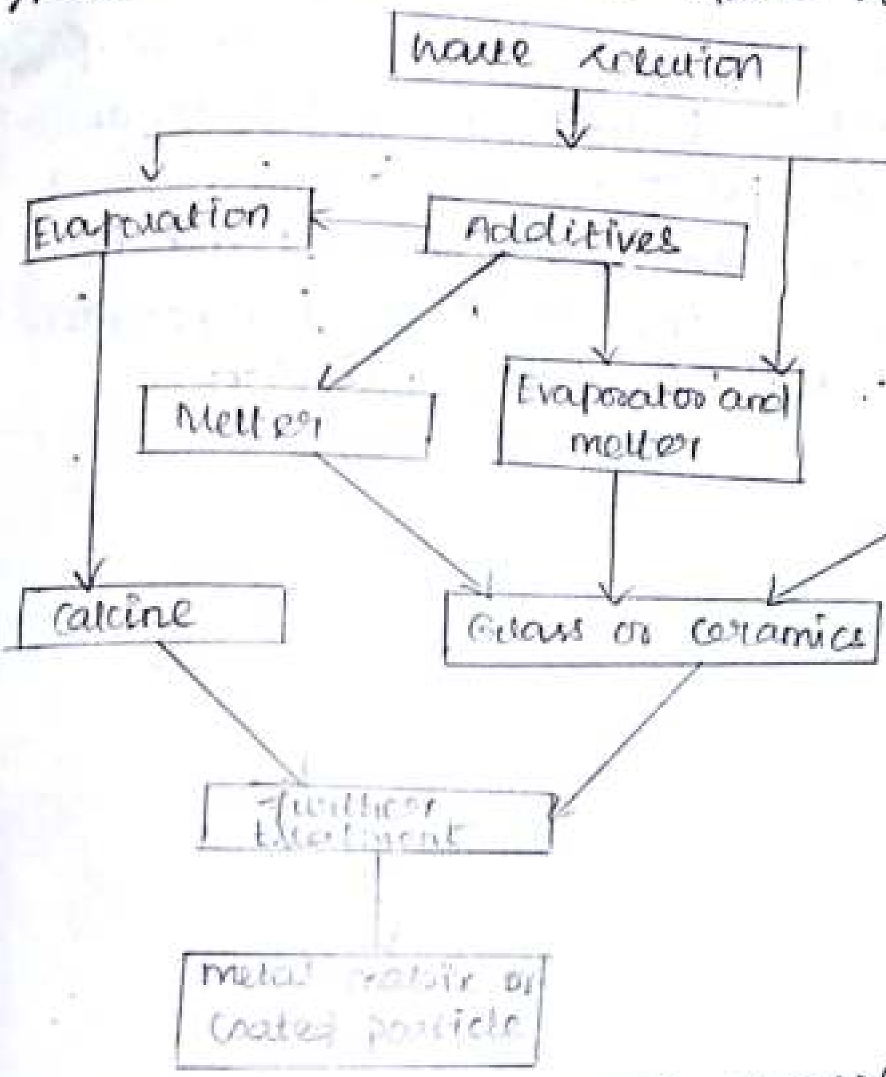
Disposal of High Level Wastes :-

Spent fuel from the nuclear reactor can either be stored directly or reprocessed. The storage system avoids the cost and hazards associated with a reprocessing plant. The second method utilizes reprocessing of unused Uranium and converted into plutonium and other radio isotopes for the use in wide variety of services such as isotope generators, medicine, agriculture and industry.

Reprocessing of the spent fuel is done by dissolving it in nitric acid and then removing the converted plutonium and unspent Uranium by solvent extraction. The remaining solution contains more than 99.99% of the non-volatile fission products plus some constituents of the cladding of fuel elements, traces of plutonium and Uranium

The remaining solution consists of high level wastes. It is usually concentrated by evaporation. It is then stored as an aqueous nitric acid solution usually in high integrity stainless steel tanks. However, the permanent storage in liquid form requires continuous supervision and tank replacement over an indefinite period of time.

The conversion of the liquid wastes to a solid form is very important. It avoids leakages. It requires less supervision and it is more suitable for final disposal. Advanced processes are currently being developed. This solid product should maintain its mechanical strength, Ideally, it should have a low leak rate.



Basic high level waste solidification processes.

Glasses and ceramics are now considered to be most suitable forms for this final disposal. The basic processes. It involves in evaporation and de-nitration to form a granular or solid Calcine. It is considered an interim product, since it does not meet all above requirements. It is treated further by being mixed with additives and it is then melted to form glasses or ceramics.

A second process involves mixing of additives with the original waste solution, evaporating, de-nitrating and melting this mixture to form glasses or ceramics.

A Third process uses an adsorption process and treatment at high temperature to produce ceramics.

Most solidification plants produce steam from off-gases and oxides of nitrogen that usually contain some fine particulate carryover and volatile radio-nuclides. These gases must be treated. All processes involve high temperature as well as high level of radio activity.

29/5/17