Hydro-Electric Plants

The hydro power plays very important role in the development of the country. as it provides ~~water~~ power at cheapest rate being perpetual source of Energy. Nearly 20% of the total world power is generated using hydro-plants. There are some fortunate ~~countr~~ countries in the world where 90% of the nation's power is met with hydro ~~electric~~ power.

As per the estimate of the world power Organization, the hydro potential is roughly 5000 GW where as only 200 GW is presently developed (4% only).

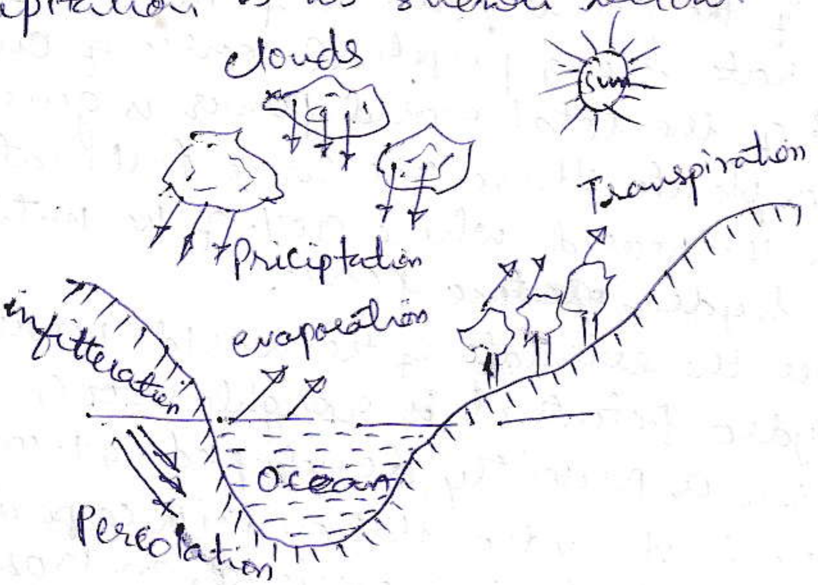
(In 1897, the first hydro-station with capacity of ~~20~~ 200 KW was installed at Darjeeling, In 1902 at Shivansamudra, ~~4~~ 4500 KW, In 1914 hydro plant of 1550 KW was installed at Gokak falls)

Hydrological Cycle

It is essential to study and measure the quantity of rainfall and water flow available to establish a hydroelectric plant.

Hydrology :- The science which deals with rainfall and run-off is known as hydrology. The ~~evap~~ evaporation of the water from the surfaces of the rivers and oceans and its precipitation on the earth is known as hydrological cycle. The distribution of precipitation on the earth's surface and beneath the earth is calculated with the help of hydrological considerations.

Water is evaporated from plants, rivers, oceans and carried with air in the form of vapour which is known as clouds. When vapour in the atmosphere is cooled below dew point temperature, it falls in the form of water or snow depending on the atmosphere temperature. The evaporation and precipitation is a natural & continuous process and therefore constitutes a perennial source of energy. Process of evaporation & precipitation is as shown below.



The hydrological cycle involves the following processes

1) Evaporation:- This is the major means of depletion of water from the earth's surface into the atmosphere. The water sources on the earth's surface is converted into vapour by the solar energy. A higher temperature, lower humidity and high rate of wind flow are major factors that assists in the water vaporization process.

2) Seepage:- It is also known as ~~see~~ infilteration. It is the process of water entering into the ground. The water on the earth surface percolates through the soil and forms ground water or water table under the earth's crust. In fact, this water is derived in the form of bore-well water, springs, open well source and so on.

3) Transpiration:- It is the process of water evaporation by the plants. All the plantation and vegetation on the earth absorb water through their roots, and release it through their leaves to the atmosphere in the form of vapours.

4) <u>Run-off</u> - It is the remaining part of the ~~water~~ precipitation water after evaporation, seepage and transpiration available on the earth's surface. Depending upon the altitude at which it is available it possesses the potential energy, and starts flowing towards the lower levels through the streams and rivers, till it reaches the sea.

The rain received and the run-off just at the reservoir will not be sufficient to store enough water for power generation. Hence, reservoir construction is made in such a way that, the run-off from the large area flows into the reservoir. The part of the land from where the run-off flows into the reservoir is called <u>Catchment area</u>. Also the part of the land from where the water starts flowing is known as <u>Upstream</u>, while the lower portion of the reservoir which receives water is known as <u>downsteam</u>.

<u>Railfall and its Measurement</u>

The rainfall, known as precipitation, is the natural process of converting atmospheric vapour into water.

or

It is defined as total condensation of moisture from the atmosphere that reaches the earth, including all forms of rains, ice and snow. The total rainfall or precipitation is given by

$$P = R + E + S + T$$

where P = Rainfall or precipitation

R = Run-off

E = Evaporation

S = Seepage

T = Transpiration.

Precipitation:- It includes all the water that falls from the atmosphere to the earth's surface. It occurs in two forms i,e rainfall (liquid precipitation) and snow fall.

Run-off:- It is the portion of the rainfall that is available on the earth's surface and flows towards streams, lakes and oceans. Sufficient run-off is available only when rate of precipitation exceeds the rate of water seepage, filling the soil pores, evaporation and other water losses. Hence, a good run-off depends on the intensity & the duration of railfall.

Evaporation:- It is the process of conversion of water into vapours from all the available sources on the earth's surface and entering into the atmosphere

Transpiration:- All the plants on the earth's surface absorb water through their roots and release it through their leaves into the atmosphere in the form vapour. This process is termed as transpiration.

Measurement of Rainfall

Rainfall is measured interms of milimeter of water during a given period of time. "One milimeter of rainfall is defined as the quantity of water collected on a plain area due to rainfall to a height of one milimeter in a standard measuring gauge. It is assumed that, there are no losses due to evaporation, seepage, transpiration and there is no run-off also during accumulation of water.

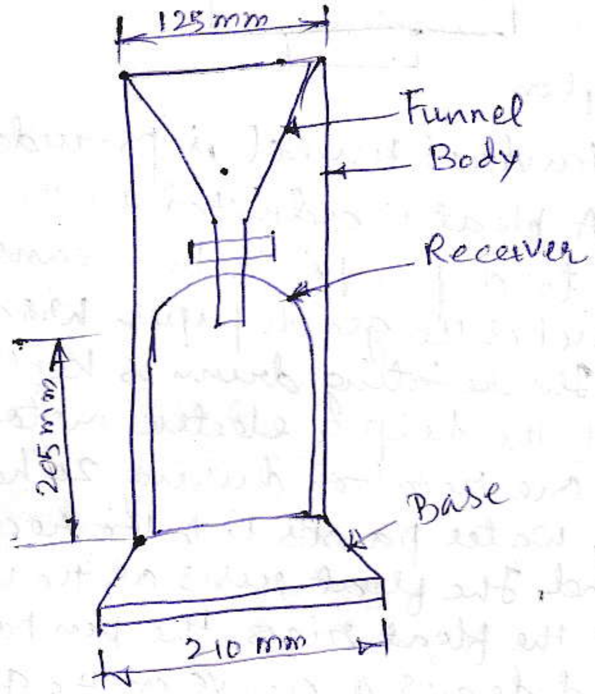
Methods of Measuring rainfall

There are two methods of measuring rainfa[ll]

1) Non Recording gauge
2) Recording gauge.

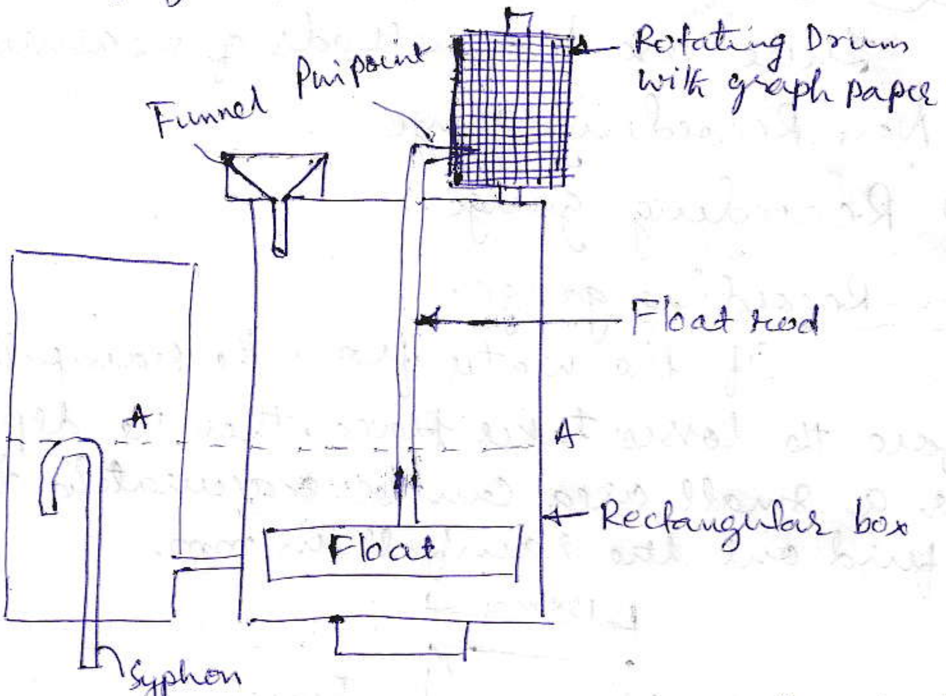
① Non-Recording gauge

If the water from the rainfall is collected before the losses takes place, then the depth of water over a small area can be accurately determined to find out the rainfall in mm.



The non-recording gauge consists of standar[d] funnel discharging into a receiver large enough to h[old] the maximum possible day's rainfall. The funnel and receiver are placed in a metal casing with suitable packings. At regular intervals, the water is collected into a measuring vessel which is calibrated to read directly the rainfall in terms of mm. The base of the gauge is permanently fixed in a concrete block at a site where rainfall is to be measured. Generally the gauge is fixed at a height of about 30 cm or 300mm above the surface level.

Recording gauge



A standard funnel is provided on the top of rectangular box. A float is adjusted in the same box. The float is connected to a pin point by means of float rod. The pin point touches the graph paper wrapped on a rotating drum. The rotating drum is kept rotating continuously with the help of electric motor. The drum makes generally one rotation during 24 hours. When rainfall occures, water passes into the rectangular box through the funnel. The float rises as the water level in the box rises. As the float rises, the pin point moves up on the graph and draws a curve on the graph sheet. Since the plot is continuous it records the cumulative rainfall, and the plot is termed as mass curve.

When the box gets filled to a level shown by A-A, the syphon starts working and all the collected water is drained out from the box. Once the box is empty, the new recording process continues.

Weighing type recording gauge is commonly used for the field work instead of floating type, because they record rain as well as snow. In this type of gauge, the precipitation passes through a collector to a bucket which is supported on the platform of a spring balance. The movement of the balance is transmitted by means of suitable levers & links to a recording pen. The chart on the drum shows ~~....~~ accumulative rainfall.

Recording type gauges are generally prepared in remote area (Forest) where ~~...~~ daily going is not possible. The gauge also records the exact duration of rainstorm and variation of rainfall intensity.

<u>Run-off & its measurements</u>

As the rain falls upon the drainage basin, a portion of it is evaporated directly by the sun, another large portion is taken up by the vegetation and growing crops particularly in growing season and some percolates into the ground. The remaining portion of rainfall flows through the catchment area on the surface of the earth is known as <u>runoff</u>. The suitability of run off for power generation depends on the magnitude and time distribution of flow and head made available by the surrounding ~~topog~~ topography. In general, the runoff is given by

$$R = P - L = R_s + R_c$$

where

R = Run-off

P = Precipitation by Rainfall

L = All losses

R_s = Runoff over the surface

R_c = Run-off reaching the catchment area.

The first step to design a hydel plant is to measure the run-off rate through the catchment area. The unit of run off is cum/sec or day-second-meter or $(Km)^2$-cm/hr

(Day-second-meter is the flow collected at rate of 1 cum/sec for one day $= 1 \times 24 \times 60 \times 60 = 86400\ m^3/day$,

$(Km)^2\text{-cm/hr} = 1000 \times 1000 \times \frac{1}{100} \times \frac{1}{3600} = 2.78\ m^3/sec$

Factors affecting the run-off

The following are the factors affecting the run-off.

(1) Rainfall pattern :- The runoff is more if the rainfall is heavy. The runoff increases more rapidly with increase in rainfall because the time allowed for evaporation and percolation losses is small when the intensity of rainfall is high. If the duration of the rainfall is more, the runoff also be prolonged because the soil tends to become saturated and lower the rate of seepage and humid atmosphere slows the evaporation.

(2) Character of catchment area :- The topography, shape, its vegital cover and nature of the surface and sub-surface geology have great influence upon the runoff characteristics of the catchment area. The steep and rocky surface gives more run-off.

(3) Vegetation :- The nature and ~~extent~~ extent of vegetation including crops determine the transpiration and interception losses. Vegetation particularly of forest has considerable effect upon the run-off. It consumes a proportion of the rainfall, causes interception losses and provides physical obstructions to the runoff.

(4) Geology of area :- The geology of the catchment area is fundamental importance in the consideration of runoff. Rocky area gives higher runoff than softy and sandy area.

(5) Weather conditions :- Low temperature, high relative humidity and low winds give high runoffs because the evaporation losses increase with the increase in temperature, decrease in relative humidity and increase in wind velocity. Water absorbed by the hot earth is also more which reduces the runoff

~~Use of Rainfall Records~~

~~The lack~~

Measurement of Runoff

To find out the available energy in a given river, we must know the quantity of water flowing and it's variation with time over a long period of years. For measuring the runoff, the following methods are used.

1) Use of Rainfall Records

The lack of availability of direct runoff data often makes it necessary to derive the runoff characteristics from rainfall observations and estimated losses.

The runoff is calculated from the rainfall data available for sufficiently long period by multiplying with a co-efficient known as "Runoff co-efficient". The value of runoff co-efficient is decided considering all the factors which affect runoff. Such co-efficients are noted for different types of catchment areas as given below.

Values of Runoff Co-efficients (K) for various surfaces

Garden appartment - 0.50
Commercial & Industrial - 0.90
Forest areas depending on soil - 0.05-0.10
Parks, farmland, pasture - 0.05-0.30
Asphalt of Concrete pavement - 0.85.

∴ Runoff = Rainfall x Runoff Co-efficient

$$R = P.K$$

This method is generally used for small catchment area

2) Runoff formulae

In this method, the run off is given directly in terms of rainfall for specified regions

a) Khosla's formula

$$R = P - 4.811T$$

b) Inglis formula

This formula is used for area in Maharashtra.

$$R = 0.85P - 304.8$$ for Ghat area.

$$R = \frac{(P-177.8)P}{2540}$$ Other than ghat area.

Where R = Runoff in mm

P = Rainfall in mm

T = mean temp in °C

c) Lacey's formula

$$R = \frac{P_2}{Y + \frac{3048F}{S}}$$

Where R = Runoff in mm

P = Precipitation or Rainfall in mm

F = Monsoon duration factor, which is 0.5 to 1.5 depending upon the catchment region.

S = catchment area

= 0.25 for flat regions

= 3.5 for hilly regions

These formulae are arrived by observation & experiments.

Problem

1) A lake behind Hoover Dam has a capacity of 30000 Km^2-m approximately. For how many days would this water be sufficient to a city of 10^6 population if daily requirement per person is 400 litres.

Soln Per day requirement $= 400 \times 10^6$ litres $= 400 \times 10^3 m^3$ ∵ 1 litre $= 10^{-3} m^3$

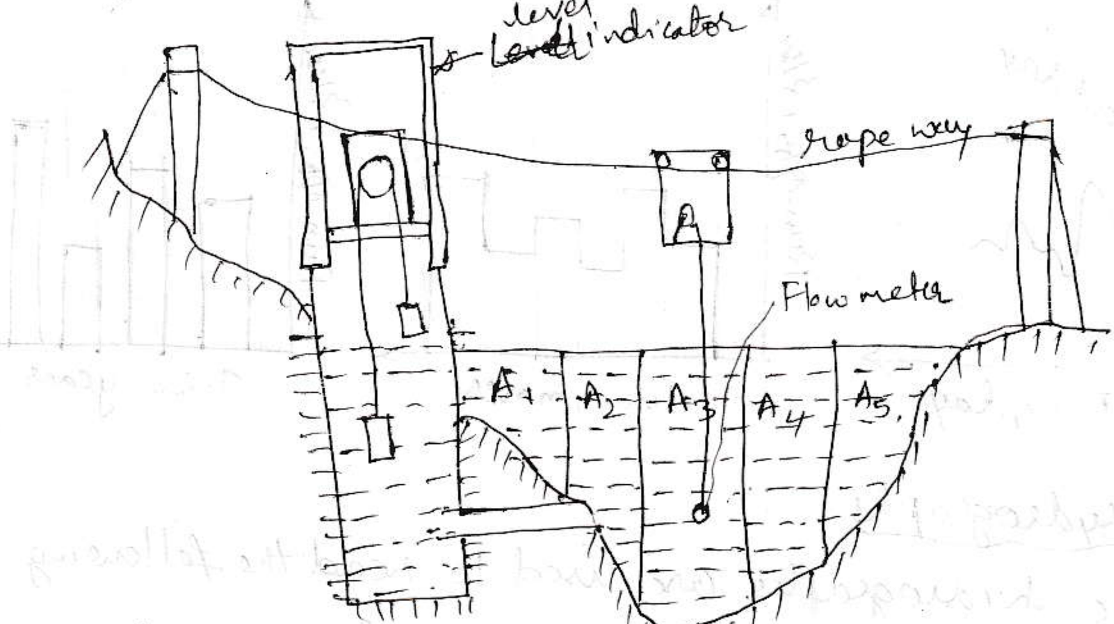
Available water in the dam $= 30000\ Km^2$-m

$= 30000 \times 1000 \times 1000\ m^2$-m

$= 30000 \times 10^6\ m^3$

∴ No of days water supplied $= \frac{30000 \times 10^6}{400 \times 10^3} = 75{,}000$ days

(3) Stream gaugeing



This is the more precise method of measuring runoff. In this method, volume of water flowing through a selected channel of fixed cross-section is evaluated by measuring the velocity of water at selected numbers of points for different stages.

The ~~deep~~ depths at different points are measured by rope arrangement. The mean velocity in each section is measured directly by flow meter. Then, run-off through the sections considered is impressed by the relation

$$Q = A_1V_1 + A_2V_2 + A_3V_3 + A_4V_4 + A_5V_5$$

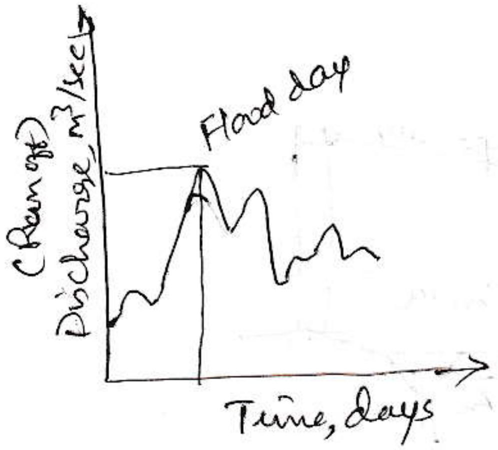
where A_1, A_2 --- are cross sectional areas of the sections

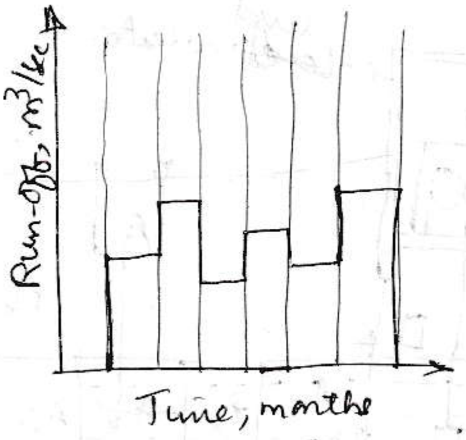
V_1, V_2 --- are the mean velocities of flow through A_1, A_2 --- resp.

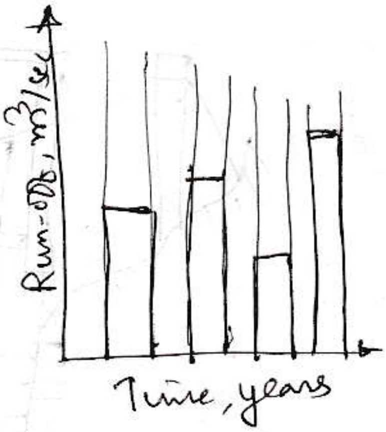
Hydrographs

Hydrograph is defined as a graph showing discharge (run-off) of flowing water with respect to time for a specified period. The time axis ~~may~~ ~~be~~ have units of hour, day, week or month. The discharge unit may be m^3/sec, Km^2-m/hr or day-second-meter. The discharge hydrographs are also known as Flood or run-off hydrographs.

The common nature of hydrographs are shown below



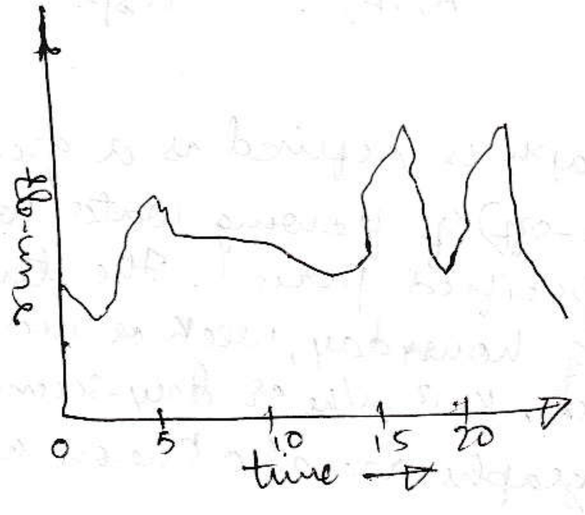




Uses of Hydrographs

The hydrographs are used to read the following

1) Rate of flow at any instant during the specific recorded period.
2) Total volume of flow in a given period, as the area under the hydrograph represents the volume of water in a given duration.
3) The mean annual run-off for each month of the year
4) The maximum & minimum run-off for the year and for each month.
5) The maximum rate of run-off during the floods and duration and frequency of the flood. The hydrograph shown below taking time period as months indicates that the flood has reached thrice in a month.



Unit Hydrograph

A unit hydrograph is a hydrograph with a volume ~~volume~~ of 1 cm of runoff resulting from a rainfall of specified duration and real pattern, which is constructed using the hydrograph data.

Flow duration curve

Flow duration curve is another useful form to represent runoff data for a given time. The magnitudes of runoff as ordinates against the corresponding percentage of time as abscissae results in so called Flow duration curve.

If the magnitude on the ordinate is the potential power contained in the stream flow, then the curve is known as power duration curve. against the percentage of time as the abscissa.

This is very useful tool in the analysis of development of water power.

A flow duration curve can be used to determine the minimum & maximum conditions of flow of water.

Example

① The mean monthly discharge for 12 months at a particular site of a river is tabulated below

Months	Discharge in millions of m^3 per month	Month	Discharge in millions of m^3 per month
A (April)	500	O	2000
M	200	N	1500
J	1500	D	1500
J	2500	J	1000
A	3000	F	800
S	2400	M	600

Draw

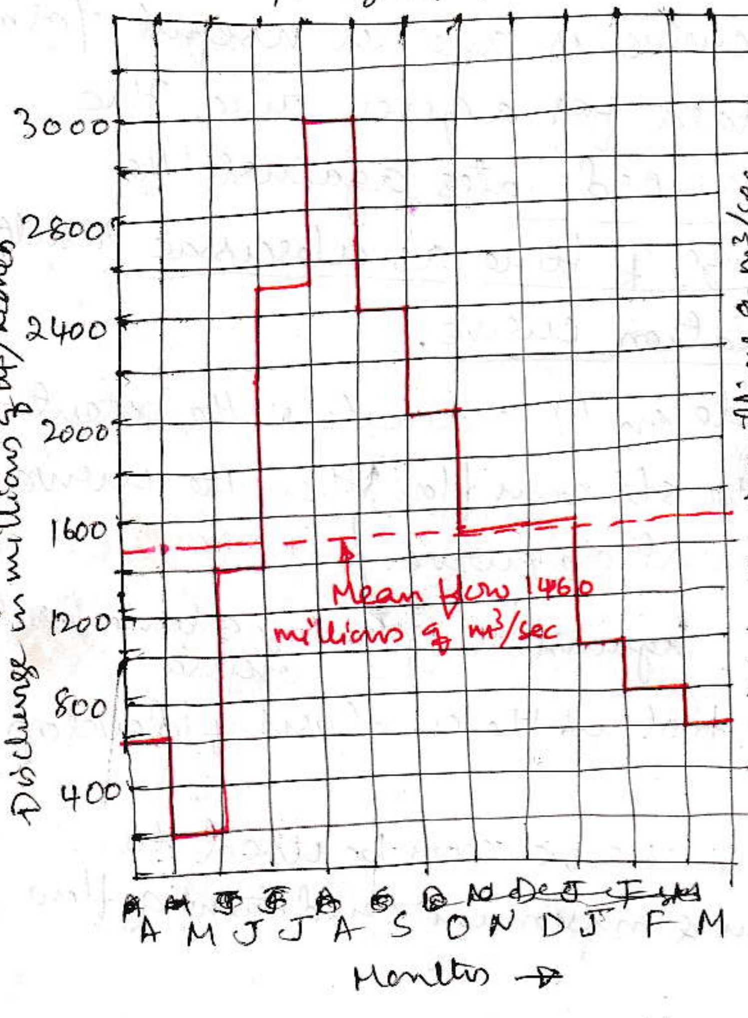
(a) Hydrograph for a given discharges and find the average monthly flow.

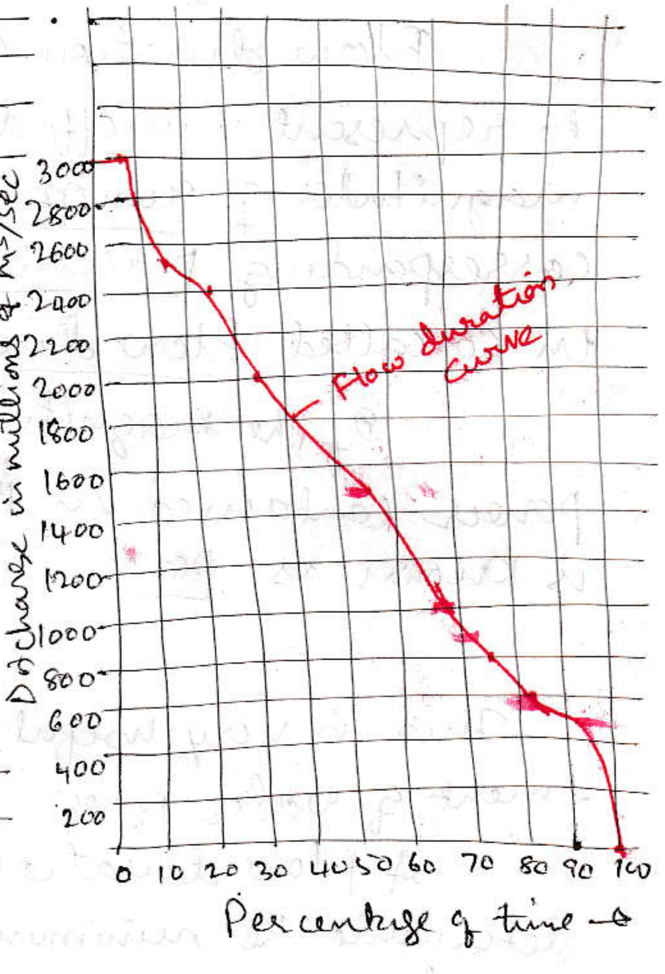
(b) The power available at mean flow of water, if the available head is 80m at the site and overall efficiency of the generation is 80%.

Take 30 days in a month.

Sol

The hydrograph can be drawn using the given runoff data.





The average monthly flow is given by

$$= \frac{500+200+1500+2500+3000+2400+2000+1500+1500+1000+800+600)}{12}$$

$= 1460$ millions of m^3/month

It is necessary to find the length of time duration which ~~contains~~ certain flows are available to obtain the flow duration curve. This information is ~~obtained~~ tabulated using the hydrograph in the following table

To obtain the flow duration curve from the hydrograph, it is necessary to find out the length of time during which certain flows are available. This information is obtained either from run off data or hydrograph. (8)

Discharge in Millions of m^3/sec (a)	Total no of months during which flow is available (b)	Percentage time duration which flow is available $C = b/12 \times 100$
200	12	100
500	11	91.8
600	10	83.40
800	9	76.00
1000	8	66.60
1500	7	58.40
2000	4	33.30
2400	3	25.00
2500	2	16.65
3000	1	8.325

By using the above available data, the flow duration curve can be drawn.

∴ The average flow available per second

$$= \frac{1460 \times 10^6}{30 \times 24 \times 60 \times 60} = 564\ m^3/sec$$

Average KW available at the site

$$= \frac{mgH}{1000} \times \eta_g$$

where m = discharge in Kg/sec
H = Head available in m
η_g = generator eff
$1 m^3 = 10^3$ Kg

$$= \frac{564 \times 10^3 \times 9.81 \times 0.8}{1000}$$

$$= 36096\ KW$$

$$= 36.096\ MW$$

(The area under the flow duration curve gives the total quantity of runoff during that period as flow duration curve is representation of hydrograph with its flow arranged in order of descending magnitude.)

(2) The runoff data of a river at a particular site is tabulated below.

Month	Mean discharge in millions of m^3 per month	Month	Mean discharge in millions of m^3 per month
J	80	J	150
F	50	A	200
M	40	S	250
A	20	O	120
M	0	N	100
J	100	D	80

(a) Draw the hydrograph & find the mean flow

(b) Also draw the flow duration curve

(c) Find the power in MW available at mean flow if the head available is 100m & overall efficiency of generation is 80%.

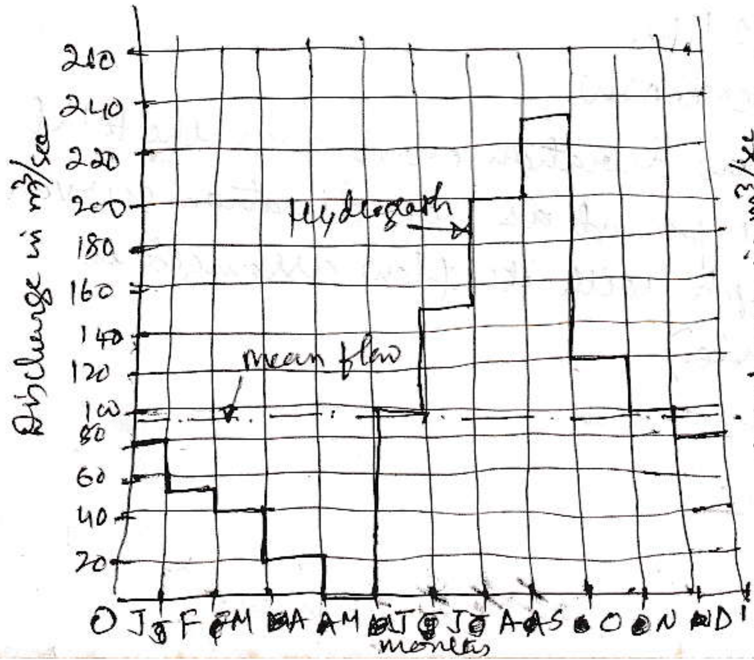
Take each month of 30 days

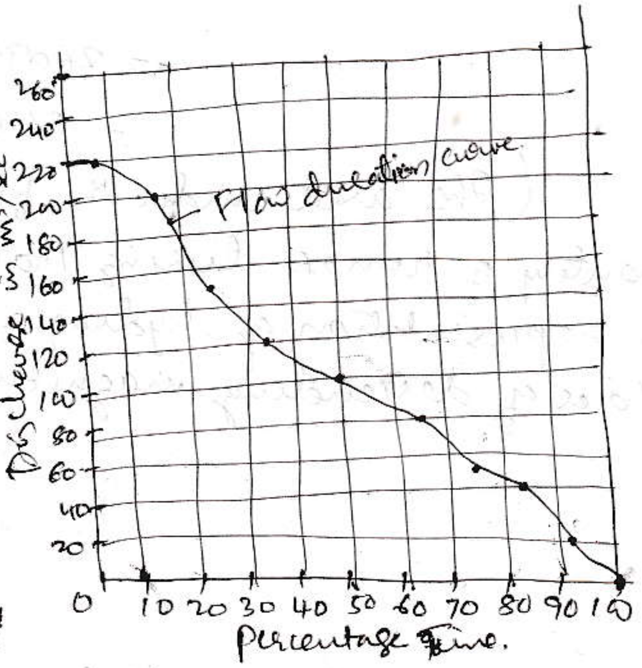
Sol:) (a) The hydrograph for the given data is drawn as shown below

The mean discharge for the given data

$$= \frac{80+50+40+20+0+100+150+200+220+120+100+80}{12}$$

$$= \frac{1160}{12} = 96.67 \text{ millions of } m^3/\text{month}$$





(b) It is necessary to find the lengths of time during which certain flows are available to obtain flow duration curve. This information is tabulated using the hydrograph in the following table.

Discharge in millions of m^3 per month (a)	Total no of months during which flow is available (b)	Percentage time $c = b/12 \times 100$
0	12	100%
20	11	91.8%
40	10	83.4%
50	9	75%
80	8	66.6%
100	6	50%
120	4	33.3%
150	3	25%
200	2	16.65%
220	1	8.325%

The flow duration curve can be drawn using the above data.

(c) Average MW energy available

$$= \frac{mgH}{1000} \times \eta_g$$

Kg/sec × m/s² × m — N-m/s — N-m/s — J/s — W

m should be in kg/sec

$$= \frac{96.67 \times 10^6 \times 10^3 \times 9.81 \times 100 \times 0.8}{1000 \times 30 \times 24 \times 60 \times 60}$$

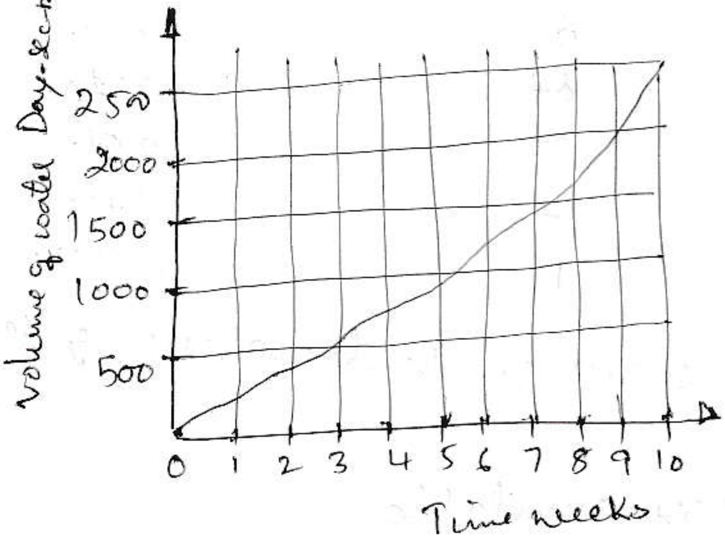
$1 M^3 = 10^3 Kg$

$$= 298.40 MW \quad 29.84 MW$$

Mass ~~[illegible]~~ curve

The graph representing the cumulative values of water quantity (run-off) against time is termed as mass-curve.

A reservoir is the means of storing water that is available during rainfall, from the catchment areas and or from a river. A mass curve is a convenient method of determining the storage ~~capacity~~ requirements of the reservoir so as to obtain a satisfactory flow from the fluctuating discharge of a river.



Mass curve

A mass curve is an integral curve of the hydrograph that represents the area under the hydrograph from one point to another. Mathematically mass curve can be given by the relation

$$V = \int_{t_1}^{t_2} Q_t \cdot dt$$

Where
V = volume of run-off
Q_t = discharge in m^3/sec as a f^n of time.

Site Selection for Hydro-Electric Power Plant

There are many factors that are to be considered while selecting site for hydel power plant, but following are the important factors.

1) Availability of water:- The site selected should be such that abundant quantity of water is to be available throughout the year for economical generation of power. To estimate the availability of water, geographical, meteorological and geological investigations of the site are to be carried out. Previous records of rainfall of the area are to be studied. If needed, arial and ground servey can be conducted. Stream flow rate, minimum and maximum quantity of water available in a year is to be estimated.

2) Storage of water:- The site selected should be such that, it should have good storage capacity, sufficient enough to use for a full year. This depends upon the reservoir capacity & catchment area. There are two types of storages in use

(a) The storage is constructed to provide just sufficient storage for one year only. In this case, there is no carry over of water for the next season. Storage becomes empty at the end of each year and becomes full at the beginning of next year.

(b) The storage is constructed to provide enough storage so it will be sufficient even during worse dry period

3) Water head:- The site selected should be such that, it should have sufficient water head for the generation of power. Head of water is the highest level of water at the upstream from where water flows down for power generation. Higher the head available, lesser the quantity of water required for known power output, and hence lesser the storage requirement. Power generated depends mainly on the head of water available, which is given by the relation

$$P = \frac{mgH}{1000} \times \eta$$

Where m = discharge of water in kg/sec

g = acceleration due to gravity in m/sec²

H = Head of water in m

η = Efficiency of primemover & generator (0.8 to 0.9)

Hence, the site selected should give highest head of water.

4) Ground water data:- The site selected should be such that, it should have lesser ground water movement as it provides a solid reservoir base and also seepage will be minimum. A strong reservoir base also helps in reducing the foundation costs for the dam construction.

5) Distance from the load centre:- It is always essential that the site selected should be nearer to the load centre. Increased distances lead to increased power transmission costs and high transmission losses.

6) Transportation:- The site selected should be such that, it should be near to the road or rail in order to reduce the cost of construction and facilitate for easy transport for labours.

7) Availability of skilled labours:- The site should be selected in such a way that, skilled labours should be available near the location.

Other factors to be considered are availability of non-polluted water for power generation, to assure safe, healthful, and culturally pleasing surroundings, to avoid health hazards, to preserve important historic, cultural and natural aspects of the site.

Advantages of HydroElectric power plant

(1) Low cost of generation
(2) Low operation and maintenance charges
(3) Renewable, non radioactive & non polluting source of energy.
(4) Reliable, clean and efficient source of energy.
(5) Inherent ability for quick starting, stopping & instantaneous load acceptance/rejection.
(6) Less labours are required ~~for~~ to operate the plant.
(7) The sites of hydel plant are usually away from the urban areas, hence the land cost is cheap
(8) Since no fuel is used, there is no problem of handling, charging and disposal.
(9) Meet peak load requirement.
(10) Flood mitigation through large storage dams.
(11) No nuisance of smoke, exhaust gases, soot & other pollutions.

Disadvantages

1) Initial cost of the plant including cost of dam is very high
2) Usually the plants are away from the load centres, which causes loss of power and high cost of transmission lines
3) It takes considerably long time for erection as compared to thermal power plant.
4) Ecosystem damage & loss of land.
5) Relocation of villages located near the site is difficult
6) Failure hazard.

Classification of Hydel plants

The hydro electric power plants are generally classified according to

1) Availability of head 100.

Ⓐ Low head plants (25 to 80 m)

Ⓑ Medium head plants (30 to 500 m)

Ⓒ High head plants (100 m and above

2) Nature of load

Ⓐ Base load plants

Ⓑ Peak load plants

3) Quantity of water available

Ⓐ Runoff river plant without pondage.

Ⓑ Runoff river plant with pondage

Ⓒ Storage type plants

Ⓓ Pump storage plants

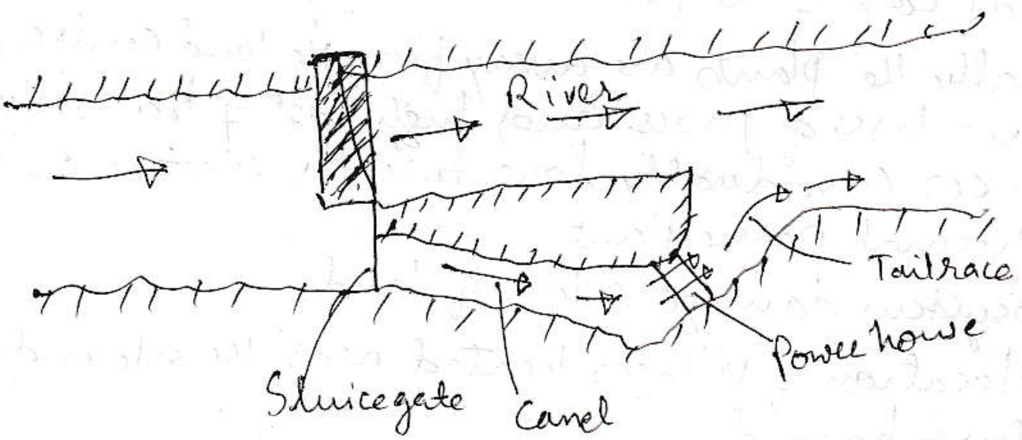
4) Capacity of plant

Ⓐ Low capacity plant (100-999 KW)

Ⓑ Medium capacity plant (1MW - 10MW)

Ⓒ High capacity plant (above 10MW)

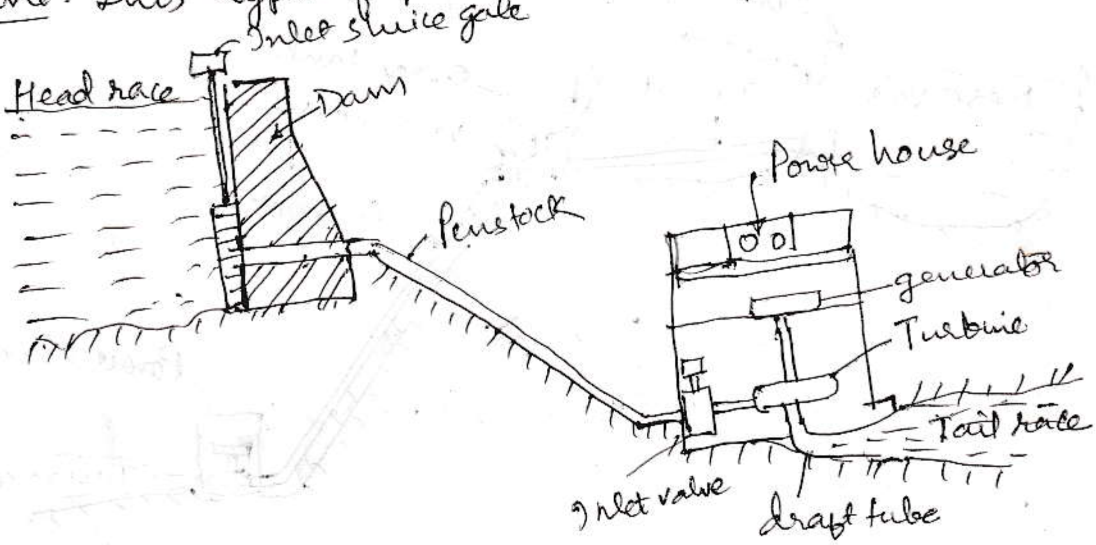
1(a) <u>Low head power plant</u>



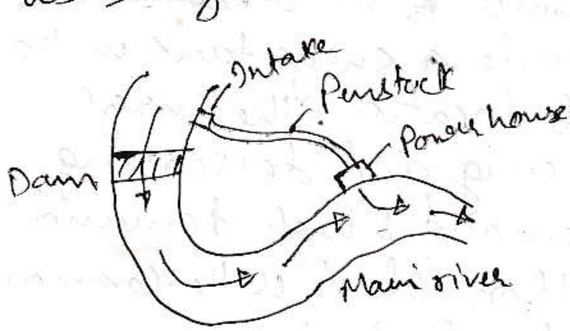
When the head of water available is below 30 m, the plant is known as low head plant. In this case, a dam is built across a river to create the necessary head of water. The excess water is allowed to flow over the dam, while the head of water is made use to run hydraulic turbines. A sideway stream diverges from the river at the dam. Over this stream the power house is constructed. Later this channel joins the river further downstream. This type of plant uses Francis or Kaplan turbine. In this case, no surge tank is required as the power house is located near the dam itself and dam is designed to take pressure created due to back flow under part load conditions.

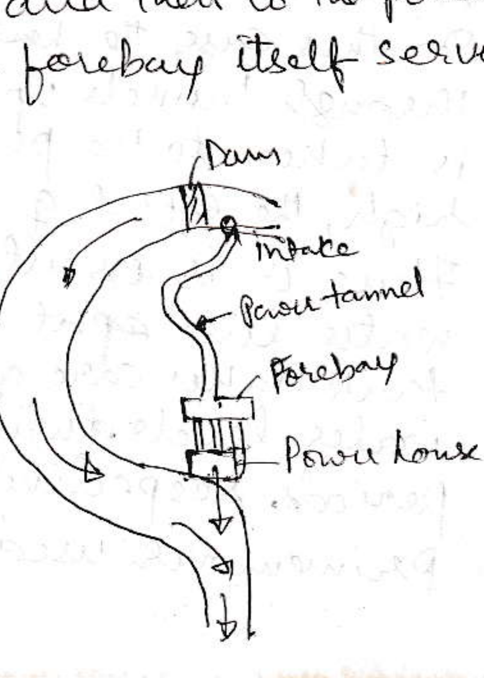
1)b) Medium Head Plant

When the operating head lies between 30 m to 100 m, the plant is known as Medium head plant. This type of plant commonly uses Francis turbine.



The forebay or small pond provided at the beginning of the penstock serves as a reservoir. In these plants, the water is generally carried in open canals from main reservoir to the forebay and then to the power house through the penstock. The forebay itself serves as surge tank in this plant.

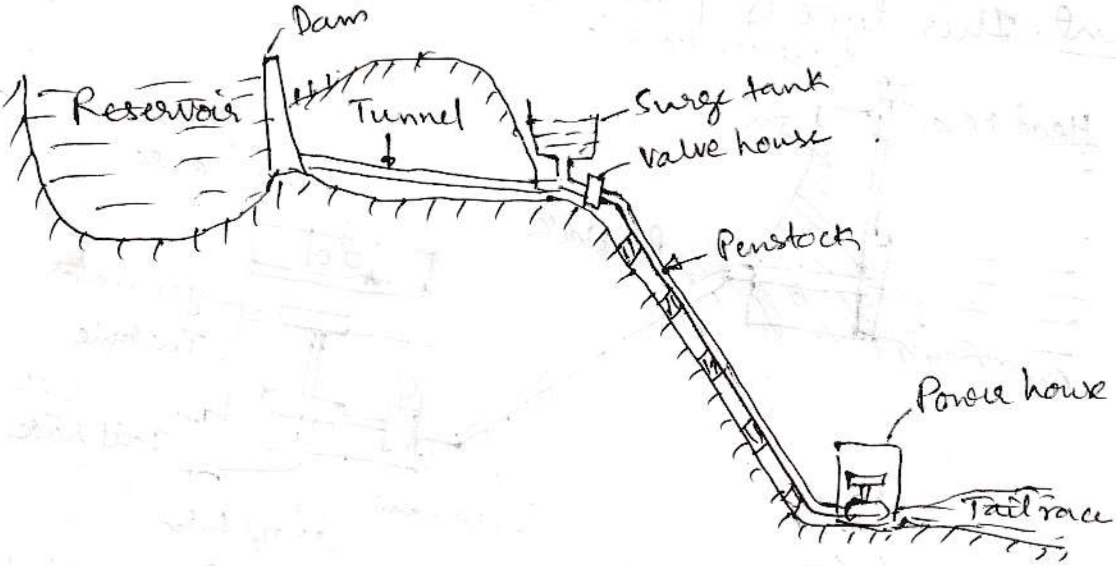




Many times, it becomes necessary to divert the water through a seperate canal to the power house, which is located sufficiently away from the diversion point. The water from the power house is discharged back into the original river at a downstream point. The distinguised feature of this plant is complicated water conveyance system.

I(c) High Head plant :-

When head of water available is 100m and more, the plant is called as high head plant.



In this type, water is usally stored in the lakes on high mountains during rainy season or during the season when ~~sto~~ snow melts. The rate of flow should be such that, the water can last throughout the year. In this case, the water from the reservoir is carried through tunnels upto the surge tank, from where it is taken to the penstock. Since the water head is very high, the effect of water hammer ~~is~~ is too ~~high~~ severe. Thus, it is essential to provide a surge tank in the water line ~~ap~~ at appropriate location. The surge tank takes care of the increasing and decreasing water levels during low demand & high demand periods respectively. The pelton wheel is the common primemover used in high head plants.

2(a) Base load plant

The plants which cater for the base load of the system are called base load plants. These plants are required to supply a constant power when connected to the grid. Thus they run without stop and are often remote controlled with which least staff are required for such plants. Run-off river plants without pondage may sometimes work as base load plant.

2(b) Peak load Plant

The plants which can supply the power during peak loads are known as peak load plants. Some of such plant work during average load but also supply during peak load as and when it is there; whereas other peak load plants are required to work during peak load hours only. The run-off river with pandage may work as peak load plants.

3)a) Runoff river plant without pondage

A run-off river without pondage, as the name indicates, doesnot store water and uses water as it comes for power generation. In such plants, the power generated directly depends upon the rate of flow available. Hence during rainy season, excess water may run waste without doing any power generation. During dry period, the production of power will be poor, since water flow rate will be low. During good flow, these plants may cater to the base load of the system.

3) b) Run-off river plant with ~~storage~~ Pondage

In these plants, Pondage usually refers to the collection of water behind the dam, the excess water available during rainy season is stored in the reservoirs. The plant works with normal runoff during the rainy season, while the stored water from the reservoir is utilized to suppliment the low flow rate during dry periods. The power production will not be affected by dry periods. Hence, plants with pondage can generate a constant rate of power throughout the year. This type of plant may work satisfactorily as base load and peak load plants.

This type of plant as compared to that without pondage, is more reliable and its generating capacity is less dependent on the flow rate of water available.

3) c) Storage type plants

If the rainfall occurs during a short period of the year and remaining period of the year is dry, it becomes essential to store water during rainy ~~seaso~~ season and supply the same during dry season. ~~A~~

A storage type plant is one with a reservoir of sufficiently large size to permit carry over storage from ~~the~~ the wet season to the dry ~~season~~, season, and thus supply firm flow substantially more than the minimum natural flow. The plant can be used as base load plant as well as peak load plant as water is available with control as required.

The majority of ~~p~~ hydro-electric plants in the world and all the plants in India are of this type.

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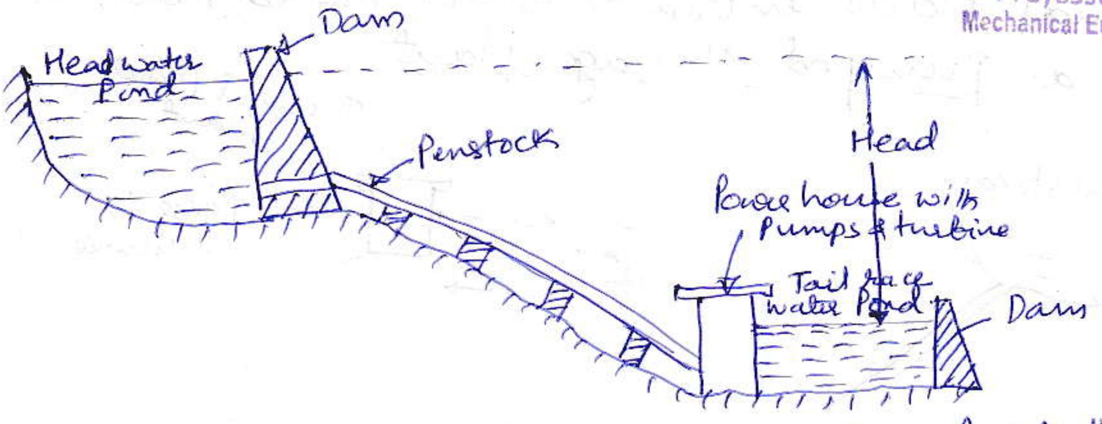
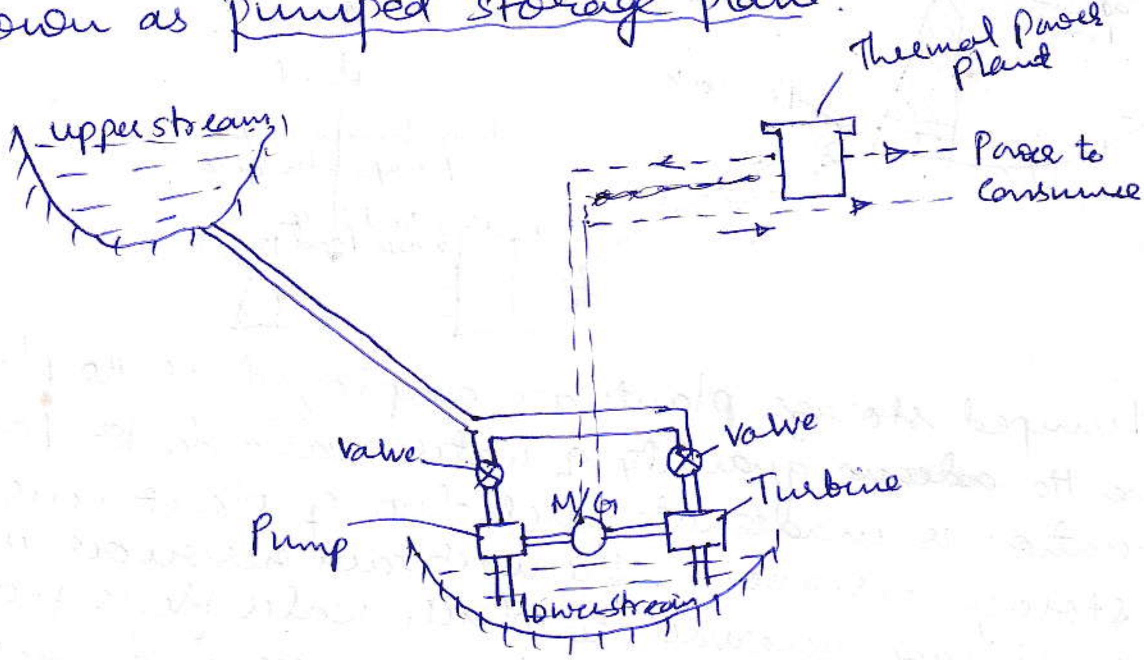
3.d Pumped storage plants



Pumped storage plants are employed at the places where the ~~adequ~~ quantity of water available for power generation is inadequate. Such type of plant consists of storage reservoirs. The upstream reservoir is the main storage reservoir to which water flows from the catchment area. The second reservoir is downstream (tail race water pond) reservoir, in which the water from the upstream is collected.

If there is shortage of water at a particular location of the plant for power generation, then the water after passing through the turbine is pumped back from tail race to head race during off peak period of thermal or nuclear plant. Pumped storage plant is a special type of hydroelectric plant. It works generally in combination with thermal plants.

If the capacity of the plant is 100MW and ~~the~~ of the load on the plant is only 80MW then instead of operating the plant at 80MW, it is operated at 100 MW and extra 20MW power generated is used to pump water from lower level reservoir to upper level reservoir and this energy is stored in the form of potential energy. Now if the load on the thermal plant increases to (say) 110MW, then 100MW is supplied by thermal plant and remaining 10MW is supplied by hydel plant. Such type of the system to pump the water from lower storage to upper reservoir when the load on the thermal plant decreases below rated load and to use the pumped water again for power generation when the load on the thermal plant increases above rated load, is known as Pumped storage plant.



Advantages of pumped storage plant

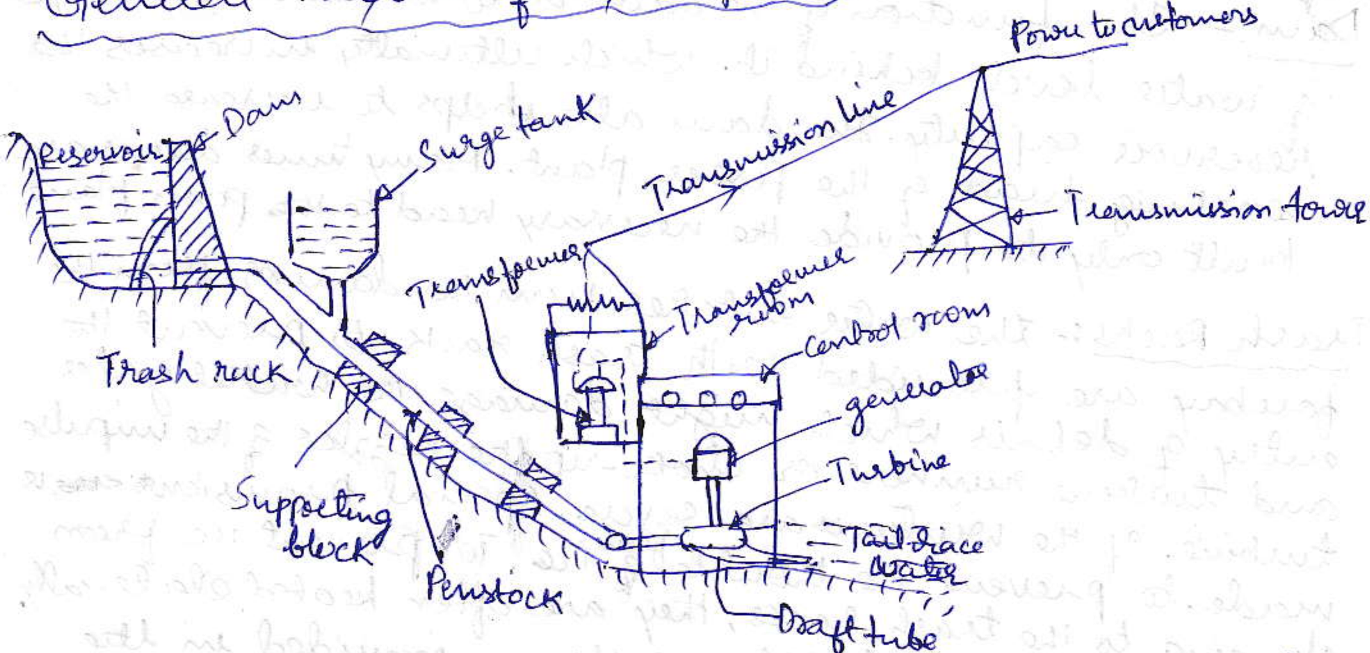
1) There is substantial increase in peak load capacity of the plant at comparatively low capital cost.
2) Due to load comparable to rated load on the plant, the operating efficiency of the plant is high.
3) Load on the hydro-electric plant remains uniform.
4) The hydroelectric plant becomes partly independent of the stream flow conditions.

Mini and Micro hydel plants

When the head of water available is between 5m to 20 m, the plant is known as Mini hydel plant.

When the head of the water available is less 5m for power generation, the plant is known as Micro hydel plant

General Layout of Hydel plant



The general layout of storage type hydel power plant with necessary components and protective devices is shown above. The main components with its functions are

1) Catchment Area:-

The whole area behind the dam draining into a stream or river across which the dam has been built at suitable place is called catchment area. A larger catchment area results in better run-off into the reservoir. The reservoir capacity and the dam size are dependent on the size of the catchment area and the intensity of the rainfall.

2) Reservoir:- The main function of the reservoir is to store water during rainy season and supply the same during dry season. The water reservoir is the primary requirement of hydro electric power plant. The water stored in the reservoir is further utilized to generate power by running the hydraulic turbines.

A reservoir may be of the following types

1) Natural 2) Artificial

A natural reservoir is a lake in high mountains.

An artificial reservoir is built by erecting dam across the river.

Dam:- The function of the dam is to increase the hight of water level behind it, which ultimately increases the reservoir capacity. The dam also helps to increase the working head of the power plant. Many times dams are built only to provide the necessary head to the power plant.

Trash Racks:- The water intakes from the dam or from the forebay are provided with trash rack to prevent the entry of debris which might damage the wicket gates and turbine runners or choke-up the nozzles of the impulse turbine. If the winters are severe, special provisions is made to prevent the trouble from ice. To prevent ice from clinging to the trash racks, they are often heated electrically. Sometimes an air bubbling system is provided in the vicinity of the trash racks which brings warmer water to the surface of the trash rack and minimizes the icing problem.

Forebay:-

The forebay serves as a regulating reservoir temporarily storing water when the load on the plant is reduced and provides water for initial increment of an increasing load while water in the canal is being accelerated. In short, forebay is a naturally provided storage which is able to absorb the flow variations. This can be considered as naturally provided surge tank as it does the work of surge tank.

Surge tank:-

It is a protective device connected to the penstock. Its function is to protect the penstock from water hammer effects during low demand periods and avoid vacuum effect during high demand periods. It acheives this by stabilizing the velocity and pressure in the penstock.

Penstock:-

A pipe between the surge tank and the prime mover is known as penstock. The structural design of the penstock is same as other pipes, except it has to bear very high pressure on inside surface during decreased load conditions on generator and on the outer surface during increased load conditions on generator. Penstocks are usually equipped with head gates at the inlet which can be closed during the repair of the penstocks. The penstocks are usually made of steel through reinforced concrete.

In a very cold weather conditions, it is sometimes advised to bury the penstock to prevent the ice formation in the pipe and reduce number of expansion joints. Uncovered penstock are usually more expensive because of the expansion joints, anchors and other apparatus required but they have advantage of being accessible for inspection and repairs.

Spillway:-

Spillway is considered as safety valve for a dam. It must have capacity to discharge major floods without damage to the dam at the same time keeps the reservoir level below the predetermined maximum level.

Power house / Prime mover

The power house is a place where prime mover is installed and run in order to generate electricity. The main function of the prime mover is to convert the kinetic energy of the water into mechanical energy to produce electric energy. The prime movers which are in common use are Pelton turbine, Francis turbine, Kaplan turbine & propeller turbine.

Draft tube :-

The draft tube is essential part of the Reaction turbine installation. It supplements the action of runner by utilizing ~~the~~ most of the remaining kinetic energy of the water at the discharge end of the runner.

Major Components & Accessories:-

A hydel power plant need many components and accessories. The type of accessories depend on the type of hydel power plant. Some important accessories are

1) DAM

The Dam is the most important and expensive structure in hydroelectric power plant. The main function of the dam is to provide head of water. The dam constructed must be stable, watertight, Low in maintenance costs, simple in construction and economic for its purpose.

Based on the construction & material used, the dams can be classified as

1) Masonry Dam
   - (a) Gravity dam
   - (b) Buttress dam
   - (c) Arch dam
2) Earthen dam.
3) Rock filled dam.

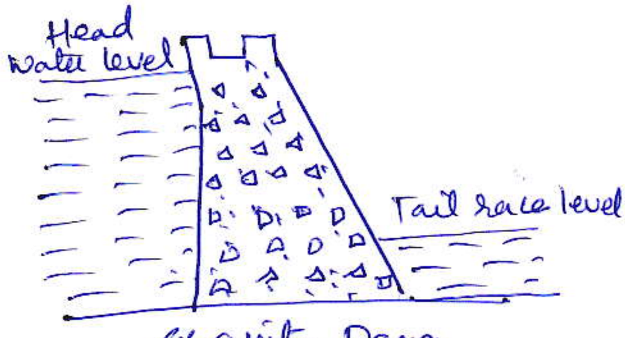
1) Masonry Dam

These are constructed using rocks and concrete. These are more stronger than other dams and have longer life. These dams are constructed for reservoirs having high head.

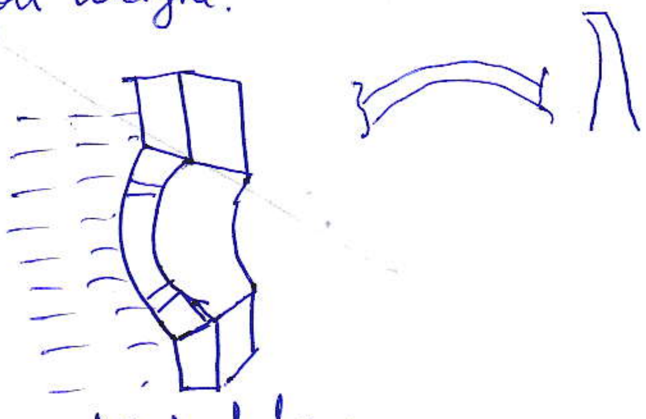
The different types of masonry dams are

(a) Gravity Dam

This type of dam is built of masonry, mortar or concrete. This dam is solid through its length except for joints in the structure to allow ~~&~~ for expansion due to temperature changes. This type of dam resists the water pressure by its own weight.



Gravity Dam



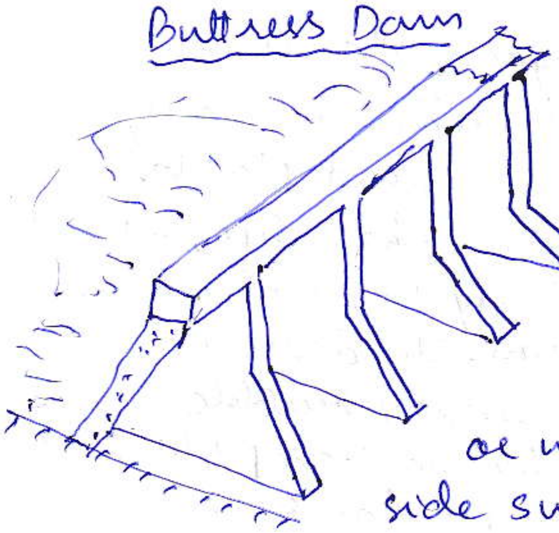
Arched dam

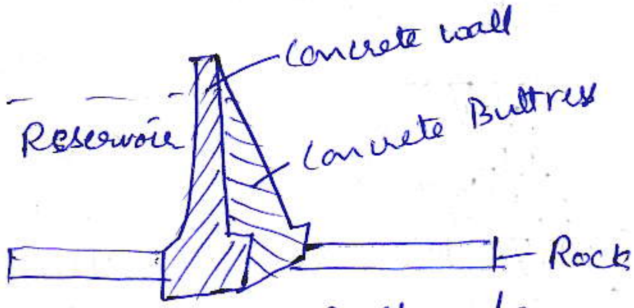
(b) Arch dam

An arch dam is a solid concrete structure, curved upstream in plan, which in addition to resisting part of pressure of the reservoir by its own weight obtains a large measure of stability by transmitting the reminder of water pressure load by arch action to the abutments.

The ~~ea~~ arch dam is safe against earthquake when reservoir ~~j~~ is full but is not considered safe when reservoir is empty. Generally such dams are constructed at narrow valleys with steep slopes.

Buttress Dam



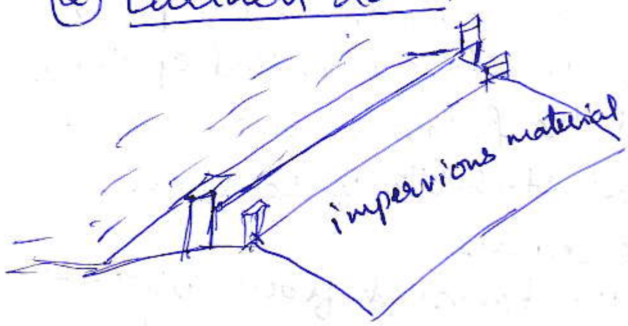


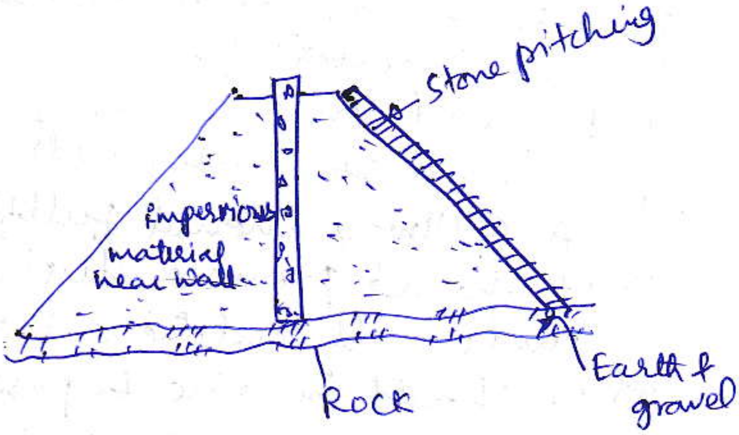
Slice of the Buttress dam

Buttress dams are made from concrete or masonry. They have watertight upstream side supported by triangular shaped walls, called buttress. The buttresses are spaced at intervals on the downstream side. They resist the force of the ~~water~~ by reservoir water trying to push the dam over.

The buttress dam was developed from the idea of the gravity dam, except that it uses a lot less of material due to clear shape between the buttresses. Like gravity dam these are suited to both narrow and wide valleys. and they must be constructed on sound rock.

(2) Earthen dam





These type of dams are constructed for small capacity reservoirs and low head reservoirs. It is constructed with a RCC core wall and earthen material. At the reservoir side a protective coating of stone is provided to avoid soil erosion by water. A safe earth dam can be built for almost any given site and foundation condition by utilizing a wide range of earth material like loose rock, gravel, sands, silts, rock, flour and clay. Actually in the interest of economy, the design of earthen dam should be adopted for the utilization of materials available near the site.

4) Rock filled dams

These type of dams are suited for medium capacity and medium head plants. They have a longer life, and comparatively they are economical in construction. The dam is constructed in three layers of dry rubble masonry, loose rockfill and protective stone pitching layer towards reservoir side. Rockfill dams have high resistance to earthquakes because of its flexible character which permits considerable movement.

Spillways and its types

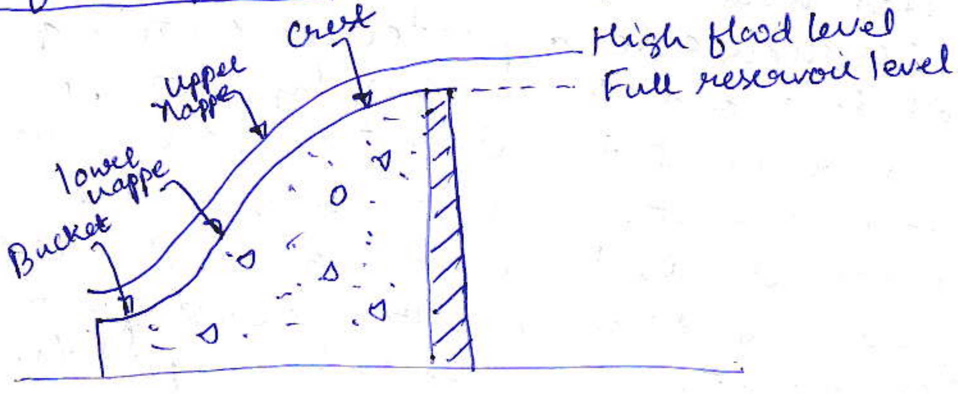
When the water enters the reservoir basin, the level of water in basin rises. This rise is arranged to be of temporary nature because excess accumulation of water endangers the stability of the dam structure. To releive reservoir from this excess water, a structure is provided in the body of the dam or on the periphery of a basin. This safeguarding structure is called spillway.

A spillway should fullfill the following requirement.

1) It should provide structural stability to the dam under all conditions of the dam.
2) It should be able to pass the designed flood without raising reservoir level above high flood level.

Types of spillways

1) Overflow spillway or solid gravity spillway

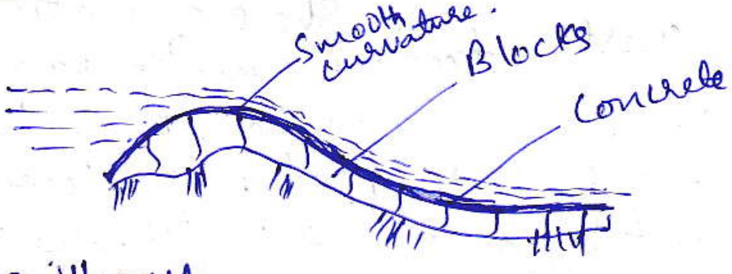


This type of spillway is provided in the case of concrete and masonry dams. It is provided in the body of the dam, generally in the centre. As it is provided in the dam itself ~~its the~~ the length of the dam should be sufficient to accommodate the designed spillway crest.

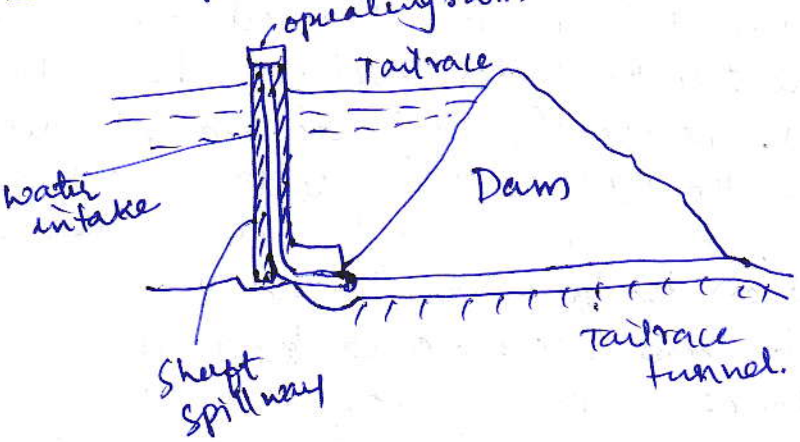
This spillway consists of an ogee crest and bucket water spills and flows over the crest in the form of rolling sheet of water. The bucket provided at the lower level of the spillway changes the direction of the fast moving water.

2) <u>Chute or ~~the~~ trough spillway</u>

This type of spillway is most suited under the situation when the valley ~~is~~ is too narrow to construct overflow spillway in the body of the dam. It is called chute spillway because after crossing over the crest of the spillway the water flow shoots down a channel to meet the river channel downstream of the dam in an excavated trench. The excavated trench is paved with concrete of 20 to 30 cm thickness. This is well adopted for earth or rockfill dam.

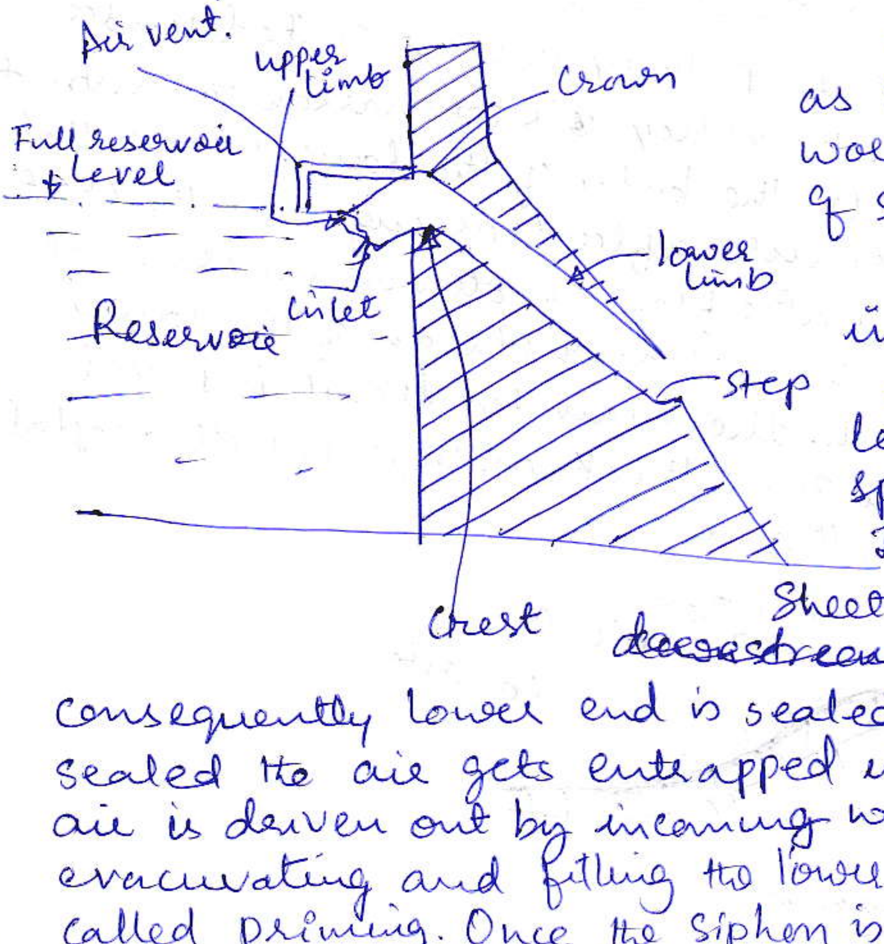


3) <u>Shaft spillway</u>



The shape of the shaft spillway is just like a funnel. The lower end of the funnel is turned at right angles and then taken out below the dam horizantally. In this type the water drops through vertical shaft and passes through a horizantal conduit which convey the water to the downstream of the dam. It is prefered where there is an inadequate space for other types of spillways.

4) Siphon Spillway



A siphon spillway as the name suggests, it works on the principle of siphon.

When water level in the reservoir is above full reservoir level, the water starts spilling over the crest. The step deflects the sheet of water and consequently lower end is sealed. As the lower end is sealed the air gets entrapped in the lower limb. This air is driven out by incoming water. The process of evacuating and filling the lower limb by water is called priming. Once the siphon is primed, the water starts flowing out till the water level goes below the full reservoir level. Generally the lower end of the upper limb is kept below the FRL in order to prevent the entrance of ice etc. To break the siphon effect, an air vent provided on the crown, through this air enters in the lower limb and blocks it.

The storage capacity above the crest can be increased by providing a movable gate. Such increase in reservoir level is allowed during low runoff period. Full spillway can be made available just by moving the gate

Penstocks :- These are the pipelines that connects between water source to the hydraulic turbines. These are usually large circular pipes with diameter ranging from 1 meter to 8 meters. Penstocks are usually made of steel or concrete pipes.

Care should be taken to keep the entry to the penstock at the dam or forebay at the lower level, submerged always under water. If the entry is open to air, it may take air along and create aeration problems in the prime mover, thus affecting the performance.

The penstocks should be laid in such a way that there are no sharp bends. Sharp bends cause frictional losses and reduce the effective water head. Generally penstocks are exposed type, since they are economical and easy to repair and maintain. However covered type are used where the regions are subjected to land sliding & snow fall.

Water Hammer in Surge tanks

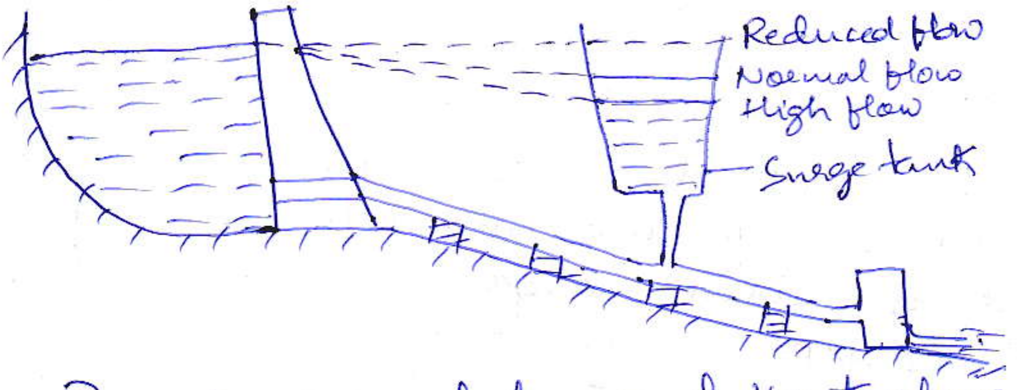
The water hammer is defined as the change in pressure rapidly above or below normal pressure caused by sudden changes in the rate of water flow through the pipe according to the demand of prime mover.

When the gates supplying water to the turbine are suddenly closed due to governer, when the load on the ~~turbine~~ generator is suddenly reduced, there is a sudden rise in pressure in the upstream of the pipe supplying water to the turbine. This sudden change of pressure in the penstock during reduction of load on turbine is known as water hammer.

Whenever there is a sudden rise in load on turbine, gates are opened instantly by the governer thereby creating vaccume in the penstock. This causes bubbling and foaming action. This leads to operational problems in the turbine. These problems can be overcome by introducing Surge tank in the penstock line.

Surge tank

Surge tank is an open tank, which is connected to the penstock and located very close to turbine. The main purpose of providing surge tank is to reduce the distance between free water surface and turbine, thereby reducing the water hammer effect on the penstock and the turbine. It also serves as supply tank ~~when~~ to the turbine when the water in the pipe is accelerating during increased load conditions as a storage tank when the water is decelerating during reduced load ~~conditions~~ conditions.



During normal demand, the turbine gates are open to the normal level, there is no fluctuation in the water level in the surge tank. The normal water level in the surge tank is always lower than that of basic reservoir level.

During low demand periods, turbine gates are closed partly and water flow is reduced to keep turbine speed constant. Due to sudden closure of the flow path, ~~the~~ the flowing water in the penstock comes to a halt thereby building pressure in the ~~line~~ line. If there is no surge tank, this creates water hammer in the penstock and may cause damage to the pipe line, With the surge tank present in the line, the sudden stopage of water flow results in an increase ~~level~~ in the level in the surge tank

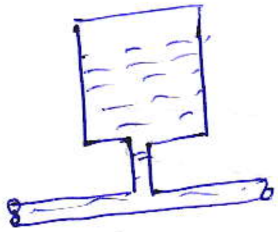
Similarly, when there is a sudden rise in the load, additional water requirement is supplied by the surge tank, thus avoiding the possibility of vacuum formation in the penstock. During this the water level suddenly drops down below the normal level as the excess water is supplied by the surge tank.

Types of Surge tanks

The different types of surge tanks are used depending upon the design and topographical requirement

1) Cylindrical Surge tank or Simple surge tank

The most simple type of surge tank is a plain cylindrical tank. It is connected to a conduit (penstock) by short connecting shaft. The tank size is kept to a level so as to maintain a stable flow to the turbine and minimum fluctuations in the water level.



This type of surge tank is uneconomical due to its large size and its action is also sluggish as compared to other types. This is not commonly used design in hydel plants.

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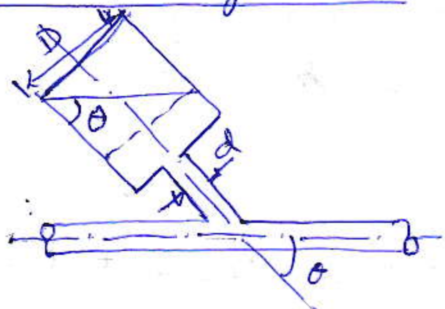
2) Inclined surge tank

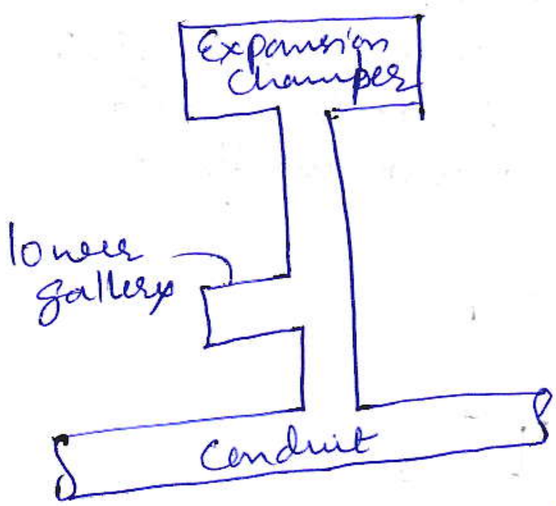


If the surge tank of diameter 'D' is inclined at an angle of θ to the horizontal, its effective water surface area increases from $\pi/4\, d^2$ to $\pi/4\, d^2 \operatorname{cosec}\theta$. Therefore lesser hight surge tank is required of the same diameter if it is inclined or lesser diameter tank is required for the same height.

However, its construction is difficult, expensive and preferred only when the topographical situations demand for such requirement.

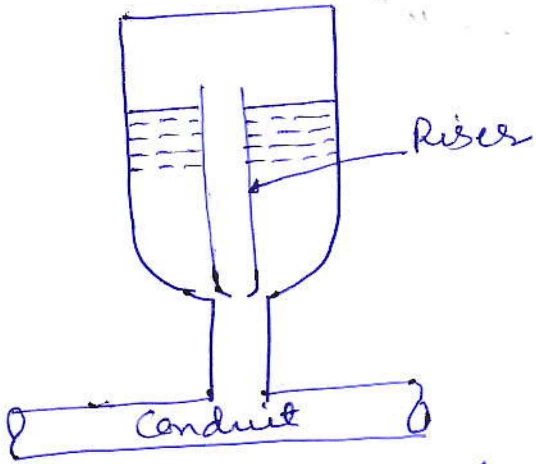
3) Expansion chamber surge tank

This type of surge tank has an expansion chamber at the top and expansion gallary at the bottom; these expansions limit the extreme surges.



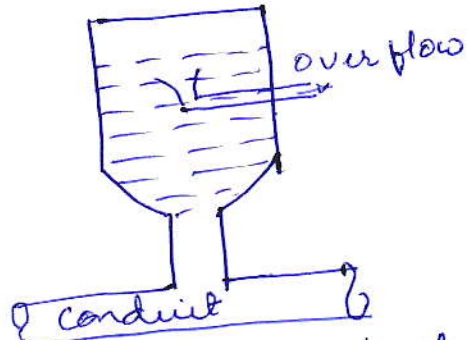
The upper expansion chamber must be above maximum reservoir level and bottom galary must be below the lowest running level in the surge tank. In addition, the intermediate should have a stable minimum diameter.

4) Differential Surge tank



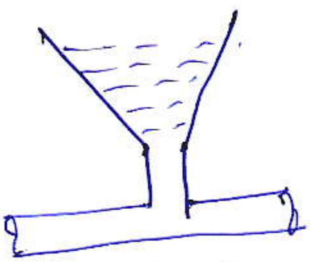
A differential surge tank has a riser with a small hole at its lower end through which water enters in it. It responds effectively to the variations in load.

5) Spillway type surge tank



This is a closed cylinderical vessel with bell mouth spillway connected to it. This tank is designed to meet water demand from the stock available in it, while the excess water during low demand periods over flows out of the surge tank through the spillway.

6) Conical Surge tank



It is conical shaped vessel connected to the penstock. It is better design than the cylinderical surge tank. Since it has an increasing area of cross-section, it can handle the water fluctuations more effectively. Also, it has a considerably faster response to load fluctuations.

Unit III

(20 marks)

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Diesel Engine Power Plant

Diesel engine power plants are suitable for small to medium power outputs. Diesel electric plants in the range of 2 to 50 MW capacity are used in these days. These are also universally ~~accepted~~ adapted to supplement hydro-electric or thermal stations where stand by generating plants are essential for starting from cold and emergency conditions.

Types of Diesel Engines used For Diesel power plants

The diesel engines are generally classified ~~with~~ as four stroke and two stroke engines.

The four stroke engine develops power after every two revolutions of the crank shaft whereas two stroke engine develops power with each revolution of crank shaft. Generally two stroke engines are favoured for diesel power plants

Dual Fuel Engine

In dual fuel engines, gas and oil both are used as fuels for the engines. The gas is used as main fuel and oil is used as supporting fuel for ignition.

In the dual fuel engine, the air and gas are taken in during suction stroke. Near the end of the compression stroke, the pilot oil (supporting oil) is injected into the cylinder. The compression heat first ignites the pilot oil and the burning of oil then ignites the gas. The further working process of this engine is ~~sm~~ same as conventional diesel engine.

Dual fuel engines are more economical as they make use of waste gases for their operation. The gaseous fuel may be waste from ~~sewa~~ sewage treatment plants or from the oil wells.

The dual fuel engines becomes an attractive means of utilizing gas as fuel at off-peak tariffs for the generation of electrical energy.

Advantages and Disadvantages of Diesel Power Plants

Advantages

1) Design and installation are very simple.
2) Can respond to varying loads without any difficulty
3) The Standby losses are less
4) Occupy Less space.
5) Can be Started and put on load quickly.
6) Requires less quantity of water for cooling purposes.
7) Overall ~~Co~~ Capital cost is lesser than that for Steam plants
8) Requires less operating and Supervising Staff as Compared to that of steam plants.
9) Compared to other power plants, it develops more power in a given area of space occupied.
10) ~~Compared to other power plants, the size of the diesel power plant is more~~
11) No problems of ash handling
12) The thermal efficiency is high
13) The cost of building & Civil Engineering works is low.
14) Can burn fairly wide range of fuels.
15) The lubrication system is more economical as compared with that of a steam power plant.
16) The plants can be located near the load centres, many times in the heart of the town.
17) The diesel power plants are more efficient than Steam power plants in the range of 150 mw Capacity.

Disadvantages

1) High operating cost
2) High maintenance cost.
3) Diesel units capacity is limited. These cannot be constructed in large size.
4) In diesel power plant, noise is a serious problem
5) The life of the diesel power plant is quite small (2 to 5 years or less) as compared to that of steam power plant (25 to 30 years)

6) The diesel power plants are not economical where fuel has to be imported.
7) These are not suitable for continuous operation under overload conditions.
8) Fuels of proper specification can only be used.

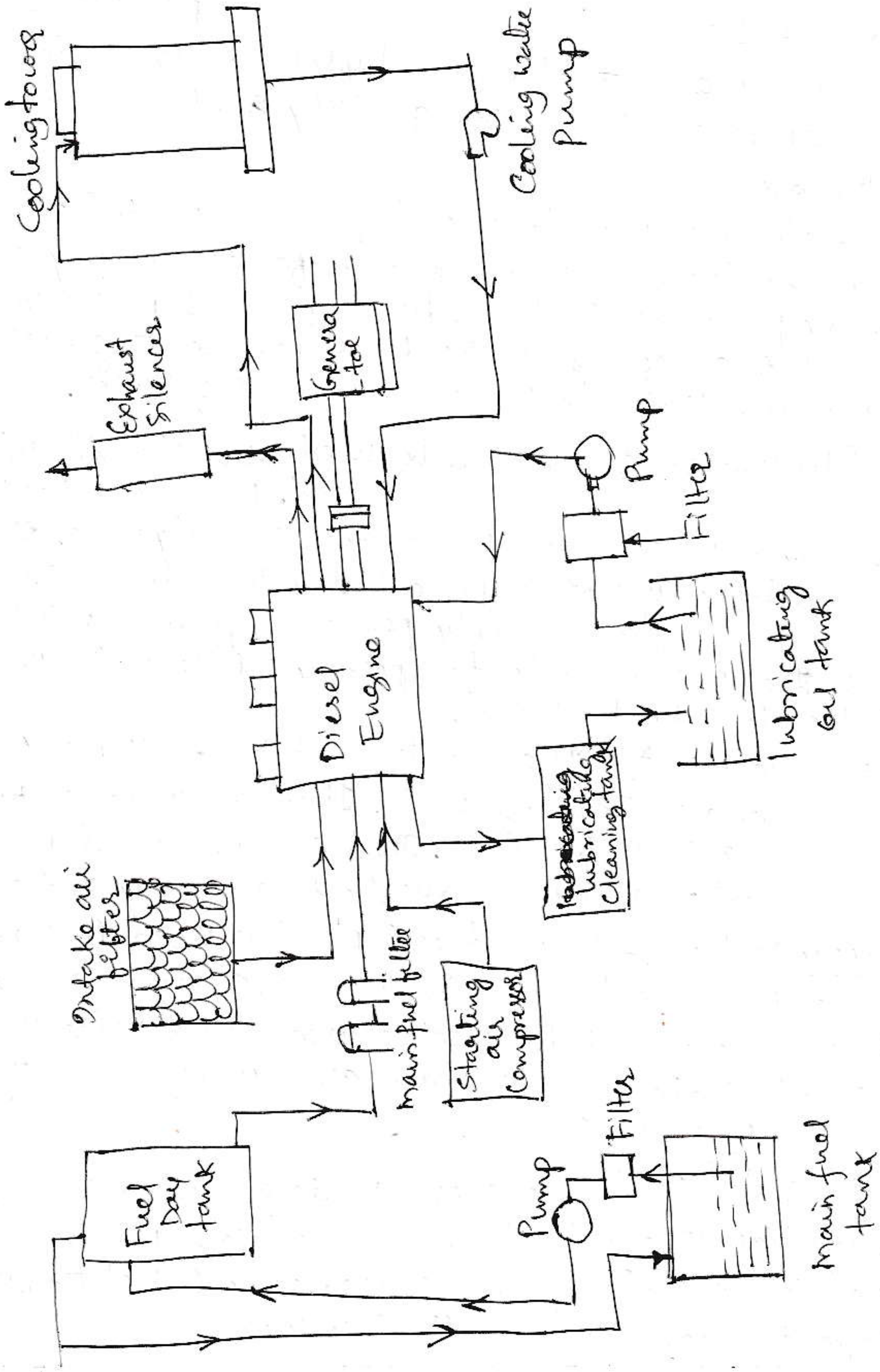
Applications of Diesel power plants

1) Peak load plants :- These can meet the peak load demands along with steam or hydel plants, since diesel engines can be started quickly and have no stand by loses.
2) Mobile plants :- Mobile diesel plants mounted on skids or ~~trailers~~ trailers can be used for temporary or emergency purposes such as for supplying power to large civil engineering works for supplimenting electrical supply system that are temporarily short of power.
3) Stand by units :- These can be used as a standby units to supply part load when required. For example, this can be used with hydel plant as a standby unit. If the water available is not sufficient due to reduced rainfall a diesel power plant supply power in parallel with hydro stations. The use is made temporary till the water is available to take full load.
4) Emergency plant :- The plants used for emergency purposes are also standby units. They are more helpful in tunnel lighting, hospitals. And are also used for telecommunication and water supply in emergency conditions.
5) Nursery station :- When diesel plant is used to supply the power to small town in the absence of main grid and which can be moved to another area which needs power on a small scale when the main grid is available is known as Nursery station.
6) Starting stations :- The diesel units are used to run the auxiliaries for starting the large steam plants.
7) Central stations :- This can be used as central station, where the capacity required is small (5 to 10MW)

8) Other applications:- Small supply units for commercial purposes and public Utilities ~~such as~~ example Cinema halls, hospital, and municipalities are commonly used places.

Layout of a Diesel power plants

The essential Components of diesel power plants are as shown in the layout.



1) Engine :- This is the main component of the plant which develops required power. The engine is generally coupled to the generator, where the mechanical energy of the ~~ead~~ shaft (engine shaft) is converted into electrical energy.

2) Air filter and Supercharger :- The main function of air filter is to remove the dust from the air which is taken by the engine.

The function of the supercharger is to increase the pressure of the air supplied to the engine to increase the power of the engine. The superchargers are generally driven by the engine.

3) Exhaust system :- This includes the silencer and connecting ducts. The temperature of the exhaust gases is sufficiently high, therefore, the heat of the exhaust gases many a times used for heating the oil or air supplied to the engine.

4) Fuel system :- It includes storage tank, fuel pump, fuel transfer pump, strainers and heater. The fuel is supplied to the engines according to the load of the plant.

5) Cooling system :- This system includes water circulating pumps, cooling tower and filteration plants. The purpose of the cooling system is to carry the heat from the engine cylinder to keep the temperature of the cylinder in the safe range & increase it's life time.

6) Lubrication system :- It includes the oil pumps, oil tanks, filters, coolers and connecting pipes. The function of the lubricating system is to reduce the friction of the moving parts and reduce the wear and tear of the engine parts.

7) Starting System :- ~~This~~ This includes compressed air tanks. The function of this system is to start the engine from cold by supplying the compressed air.

8) Governing system:- The function of the governing system is to maintain the speed of the engine constant irrespective of the load on the plant. This is done by varying fuel supply to the engine according to the load.

Site selection of Diesel power plant

The following ~~points~~ factors should be considered while selecting site for a diesel power plant.

1) Foundation sub-soil condition:- The conditions of the sub-soil should be such that a foundation at a reasonable depth should be capable of providing strong support to the engine.
2) Access to the site:- The site should be so selected that, it is easily accessible through rail and road.
3) Distance from the load centre:- The location of the plant should be near the load centre. This reduces the cost of transmission lines and cost of maintenance. The power loss is also minimized.
4) Availability of water:- The site should be selected in such a place that where sufficient quantity of water should be available
5) Fuel transportation:- The site selected should be near to the source of fuel supply so that transportation charges are low.

Essential systems or Accessories of Diesel Power Plant

There are number of systems and accessories that are essential for the successful running of a diesel power plant. Some of the important parts are briefly discussed here.

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I) Fuel Injection System

The mechanical heart of the Diesel engine is the fuel injection system. The fuel injector atomises the diesel and injects measured quantity of diesel into the engine cylinder at the end of the compression stroke. The atomised diesel then mixes with hot air and get ignited. Proper mixing of the fuel with the air is essential for the efficient power output from the engine.

Functions of fuel injection system

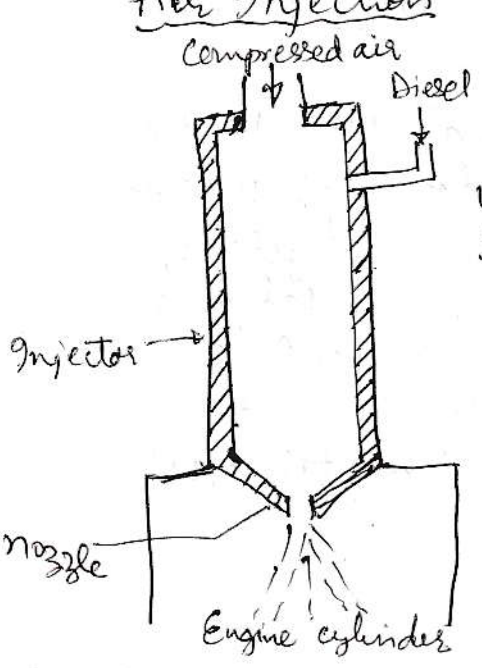
1) Filter the fuel
2) Metered or measured quantity of fuel to be injected
3) Time of fuel injection
4) Control the rate of fuel injection
5) Autonuise or break up the fuel to fine particles.
6) Properly distribute the fuel in the combustion chamber.

Types of fuel injection system

The diesel injection systems are of two types

1) Air injection
2) Airless or solid injection.
   (a) Unit Injection system
   (b) Pump injection system (Individual Pump Injection system)
   (c) Distributor Injection system
   (d) Common rail injection system.

Air Injection

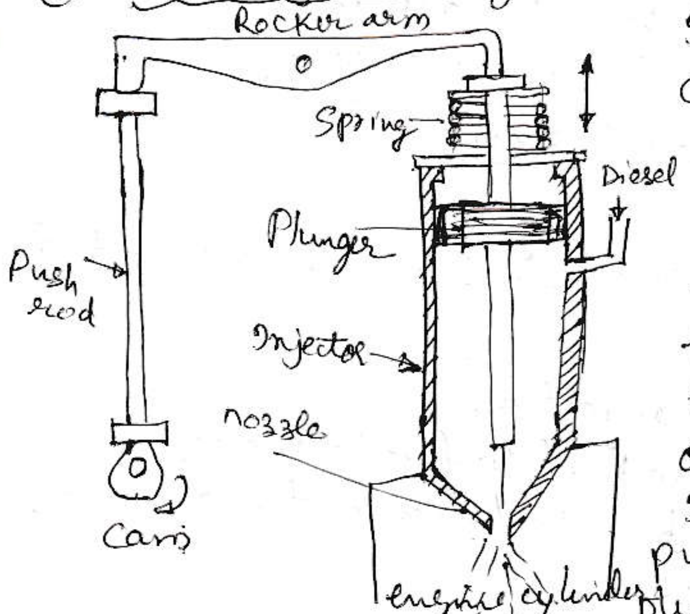


In this system, initially fuel is pumped into the injector and then high pressure compressed air about a pressure of 50-70 bar is supplied to the nozzle, which injects the diesel into the engine cylinder. The air flow valve and fuel supply valve to the injector are operated by cams, connected to crankshaft through timing gears & cam shaft. Now days this type of injection system is not used, as the pressure developed is not very high.

2) Airless or solid injection

In this system, diesel is injected into the engine cylinder at a very high pressure say about 100 to 150 bar using a plunger. ~~Flowing~~ Following are the important methods ~~of~~

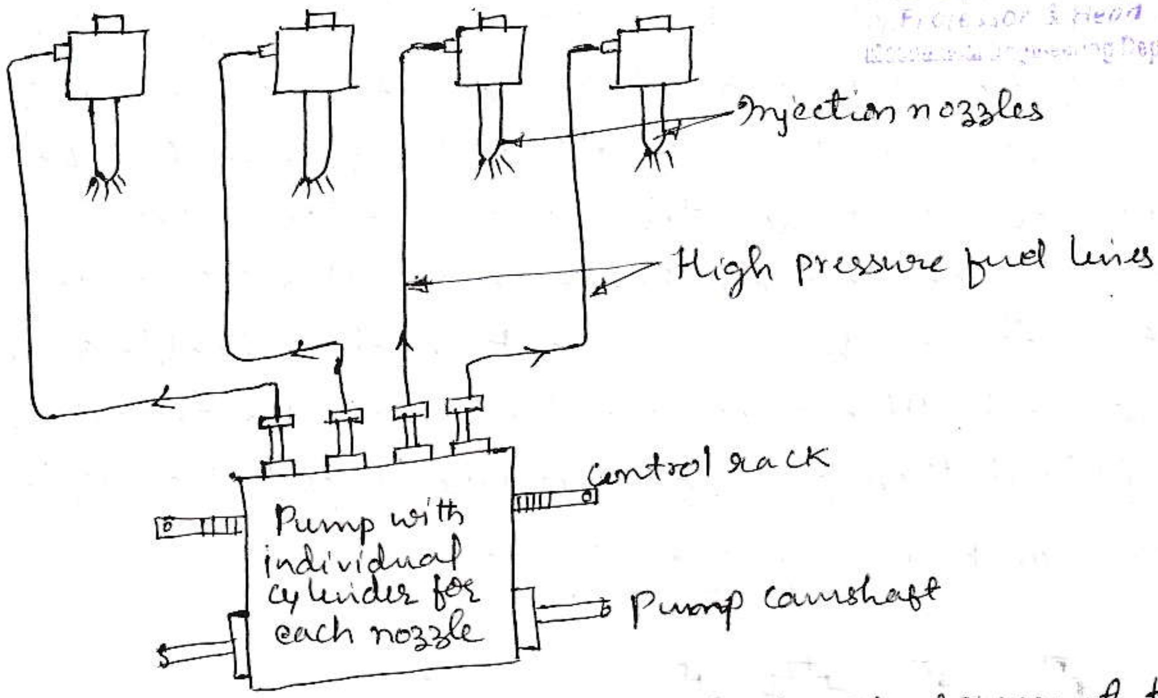
(a) Unit Injection system



In this system the injector consists of a plunger connected to a spring, rocker arm, Push rod mechanism and cam as shown in figure. The cam operated by the timing gears gives motion to the push rod, which operates the rocker arm. ~~and~~ In turn the rocker arm pushes the plunger down. The plunger pressurizes the fuel in the injector barrel and fuel is injected into the engine cylinder. There is a spring loaded delivery valve in the nozzle, which gets actuated by the increased oil pressure in the injector ~~nozzle~~ barrel. The spring at the top of the injector brings back the plunger to its upper (original) position after the operation. Now the fuel pump, pumps the fuel to the injector.

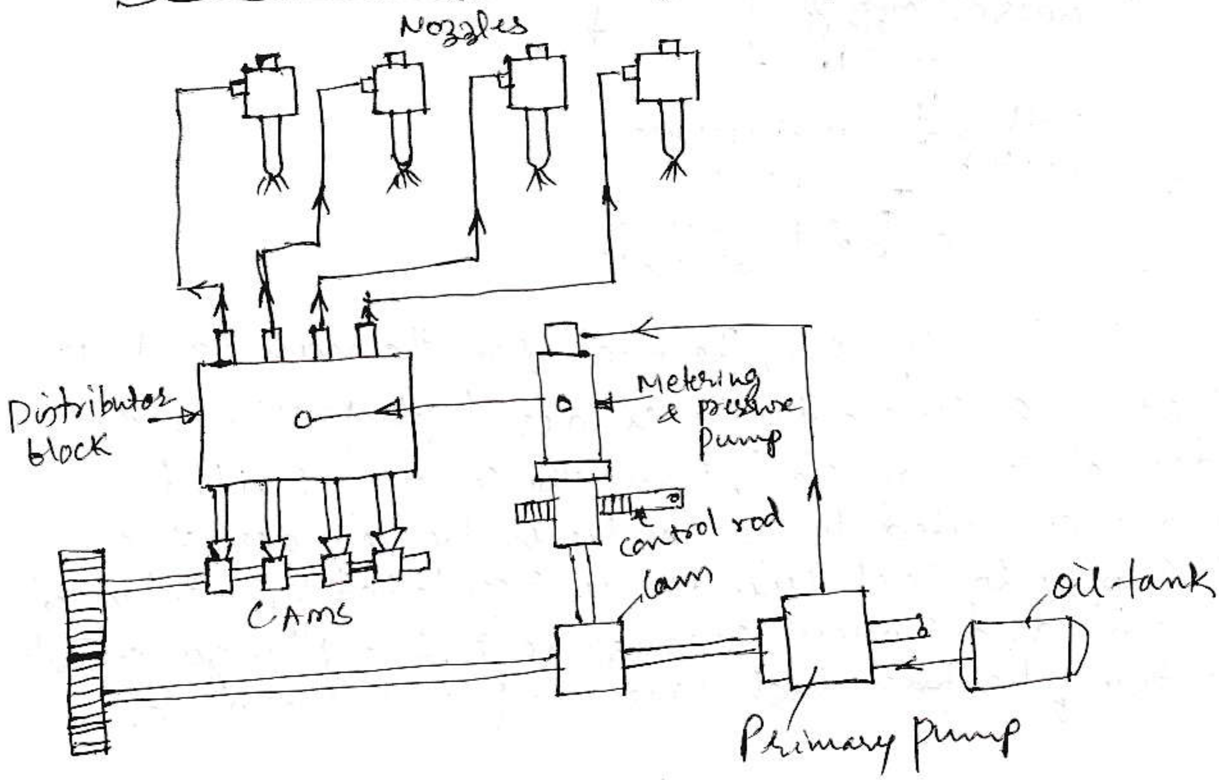
(b) Pump Injection system or Individual pump Injection system

In this system, individual pumps are provided to supply the fuel oil under high pressure to the fuel injector. The pumps in this system, are individually operated by cams, mounted on a common ~~crank~~ camshaft. The arrangement is made such that, the pump operates so as to inject the oil at the required injection time for ignition in the engine cylinder.



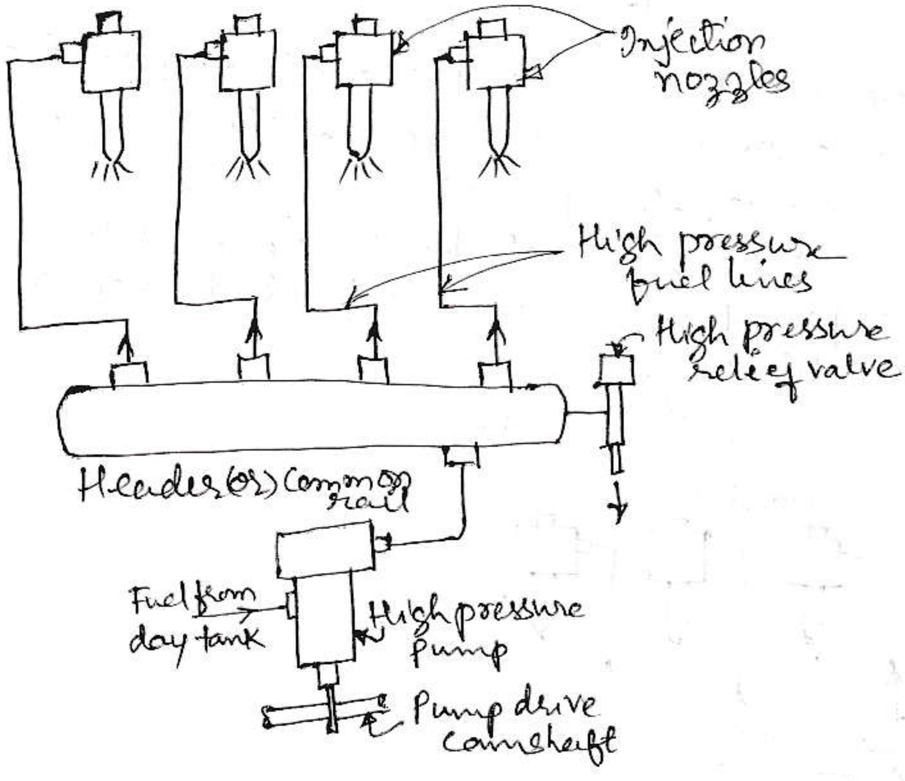
Similarly all pumps operate at different timings, corresponding to the fuel injection timing of their connected nozzles. The pressurised oil from the pumps are supplied through high pressure fuel lines to the nozzles. The pumps measure the fuel charge and control the injection timing.

c) Distributor Injection Systems



In this system a primary pump pumps the fuel oil from the main tank to the metering & pressure pump. The metering pump supplies the correct quantity of fuel to the distributor block under high pressure. The purpose of the distributor block in this system is to distribute the high pressure oil to the nozzles for the corresponding injection timing. The distributor is operated by cams mounted on a camshaft. The cam-shaft is driven by the engine through suitable gearing arrangement. The pressurised oil from the distributor is supplied through high pressure lines to the nozzles.

d) Common Rail Injection System



In this system, the fuel from the main tank is supplied by a single pump under high pressure to the header or common rail. From the common rail, fuel lines are connected to the nozzles in the cylinder. The fuel supply to each cylinder is regulated by mechanical push rod and rocker arrangement. The plunger controls the entry of the ~~fuel~~ high pressure fuel to the nozzle.

Cooling system

In an internal combustion engine, the temperature of the gases inside the engine cylinder may vary from 35°c to 2750°c during the cycle. If an engine is allowed to run without cooling, the cylinder walls, cylinder, and piston tend to assume the average temperature of the gases to which they are exposed which may be the order of 1000°c to 1500°c. Obviously at such high temperature, the metals will loose their characteristics & piston will expand considerably and sieze the liner. and also the lubricating oil ~~evaporate~~ will begin to evaporate and both ~~pis~~ cylinder and piston may be damaged.

In view of this, part of the heat generated inside the engine cylinder is allowed to be carried away by the cooling system.

Need of cooling system in an engine (Reasons)

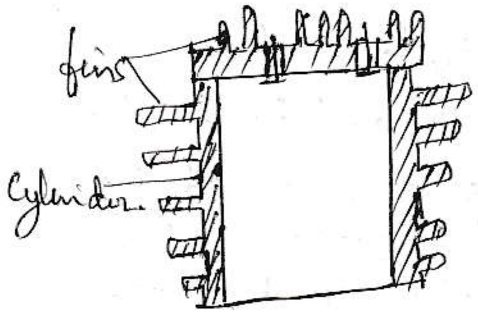
1) The even expansion of piston in the cylinder may result in seizure of the piston.
2) High temperatures reduce strength of piston & cylinder liner
3) Overheated cylinder may lead to pre-ignition of the charge in case of spark ignition engine.
4) Physical & chemical changes may occure in lubricating oil which may cause sticking of piston rings and excessive wear of cylinder.

Methods of cooling system

There are two methods of cooling IC engines are

1) Air cooling 2) Water cooling.

1) Air cooling



In this method, heat is carried away by the air flowing over and around the engine cylinder. It is used in scooters, motorcycles etc. Here fins are cast on the cylinder head and cylinder barrel which provides additional conductive and radiating surface. The fins are arranged in such a way that are at right angles to the cylinder axis.

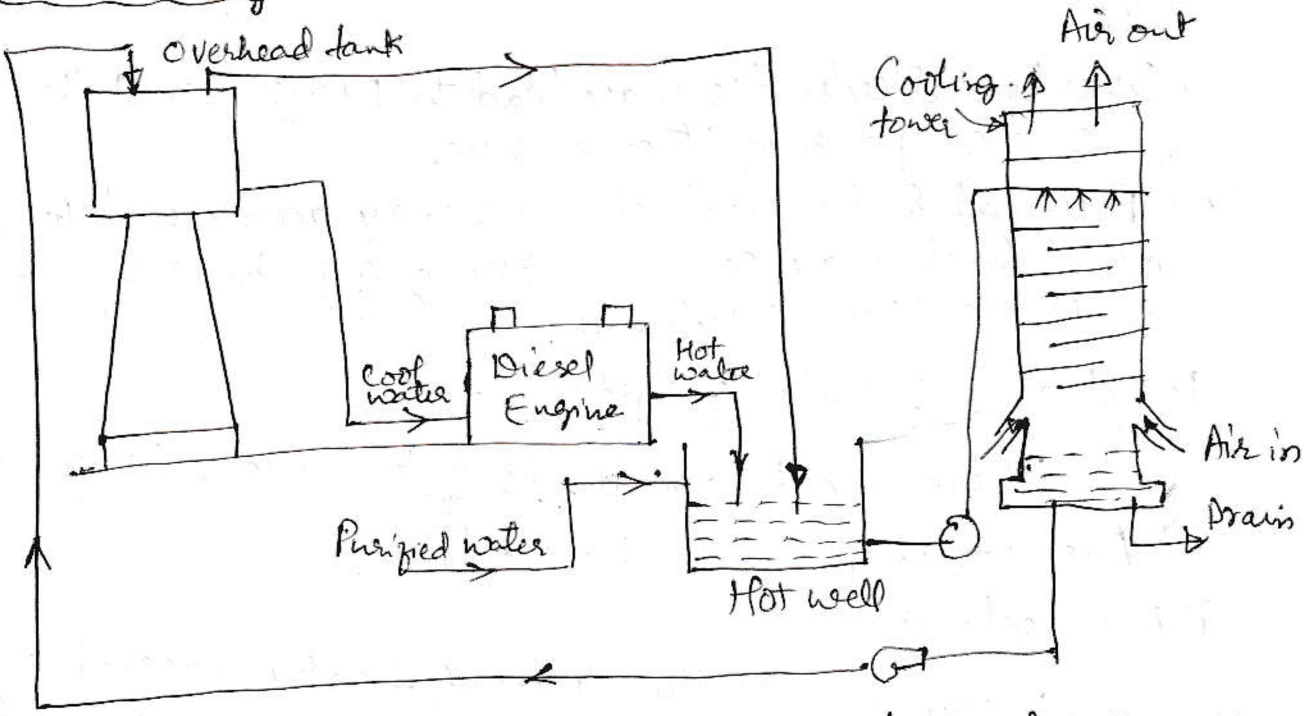
Advantages

1) The design of the engine becomes simpler as no water jackets are required.
2) Absence of cooling pipes, radiator etc makes the cooling system simpler.
3) Installation of air cooled engine is simple.
4) The weight of the air cooled engine is less than water cooled engine.
5) The engine is not subjected to freezing troubles etc usually encountered in case of water cooled engine

Disadvantages

1) Their movement is noisy
2) Non uniform cooling
3) The output of the air cooled engine is less than water cooled engine.
4) Maintenance is not easy.

2) Water cooling

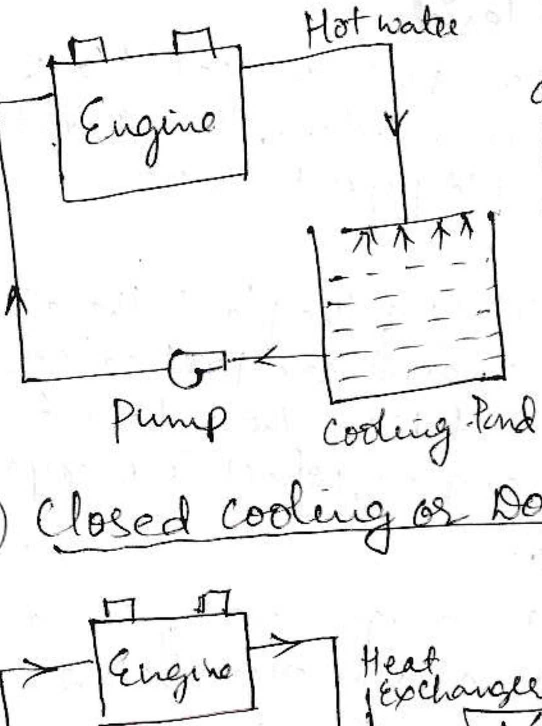


The cooling water is initially treated to remove impurities and then pumped to a overhead tank. The cooling water then flows to the engine, around the cylinder through the cooling jackets, absorbs heat & gets collected in a hot well. The hot water from the well is pumped to a cooling tower and sprayed from the top. The water flows downward through the baffles and the air is supplied from the bottom, which carries the heat from the water. The cool water is collected at the bottom of the cooling tower. The cooled water from the cooling tower is pumped back to the overhead tank for recirculation into the engine for cooling. Purified water is periodically added to hot water well to make up the vapourisation losses. This type of cooling water is suitable for medium and large capacity diesel power plant.

Based on the method of circulation of the cooling water, the cooling system is divided into two types

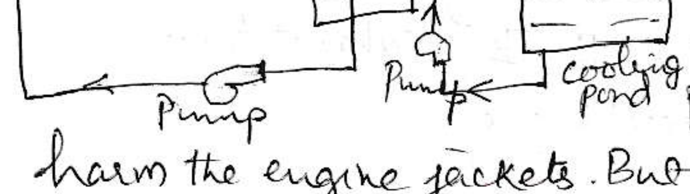
(a) Open cooling or Single circuit
(b) Closed cooling or Double circuit.

(a) Open cooling or Single circuit



In this system, the cooling water after absorbing heat from the engine is cooled in a cooling pond or tower and recirculated back to the engine. The advantage of this system is that, it is simple and economical, but leads to corrosion of cylinder jackets.

(b) Closed cooling or Double circuit



In this system, the cooling water flows in a closed circuit and gives out the absorbed heat to another circuit of water through heat exchanger. The advantages of this system is that the closed circuit with purified water does not harm the engine jackets. But system is complex & expensive.

Cooling methods 1) Thermosyphon cooling (2) Forced or pump cooling (3) Cooling with thermostatic regulator (4) Pressurised water cooling (5) Evaporative cooling.

Exhaust system

The purpose of exhaust system is to discharge the engine exhaust to the atmosphere outside the building. Another function of the exhaust system is to reduce noise level of the exhaust that is created due to the firing action and sudden expansion of the gases in the engine cylinders. The exhaust piping system is provided to meet the following requirements.

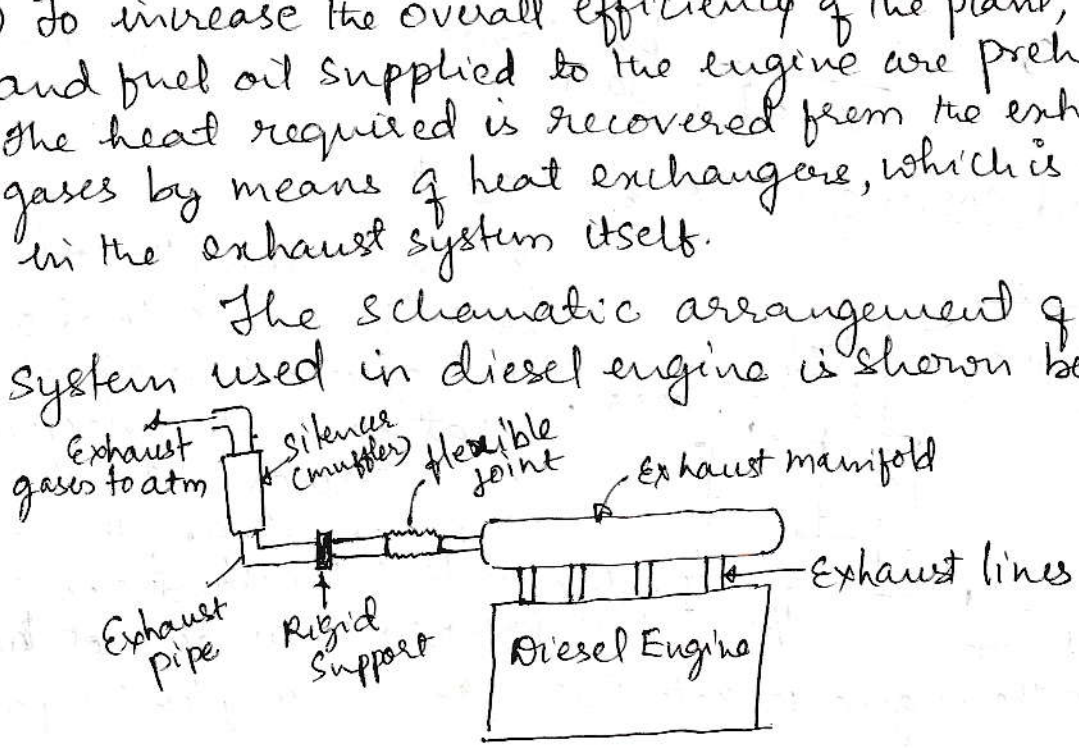
1) The combustion inside the engine cylinder takes place under high pressure and temperatures. This creates high noise level, which is ~~nuisance~~ Nuisance on the human comfort conditions. The exhaust system is thus provided with a silencer, so that the noise is reduced to a tolerable level.

2) The product of combustion from an IC engine contains carbon dioxide, carbon monoxide, sulphur and other objectionable gases, which are major air pollutants. This harms the human health. Thus the exhaust system is necessary to discharge these flue gases at a higher level well above the ground level.

3) The high pressure combustion gases are capable of causing vibrations in the piping system. Thus the exhaust system is provided with flexible pipes to overcome vibrations.

4) To increase the overall efficiency of the plant, the air and fuel oil supplied to the engine are preheated. The heat required is recovered from the exhaust gases by means of heat exchangers, which is incorporated in the exhaust system itself.

The schematic arrangement of exhaust system used in diesel engine is shown below.



The engine cylinder outlets are connected to an exhaust manifold above the cylinder head. The manifold acts as the collection point for the exhaust gases temporarily. From the exhaust manifold, the line is connected to a silencer or muffler, which reduces the noise level. The hot gases from the silencer are then discharged into the atmosphere.

The energy present in the exhaust gas can be used to drive a small turbine which in turn drives the compressor mounted on the turbine shaft. This system is used for increasing the pressure of the air before it is supplied to the engine.

Lubrication system

Lubrication is the admittance of oil between the two surfaces having relative motion. The purposes of lubrication are

1) To reduce the friction and wear between the parts having relative motion
2) To cool the surfaces by carrying away heat generated due to friction.
3) To seal the space adjoining the surfaces such as piston rings and cylinder liners.
4) To clean the surface by carrying away the carbon and metal particles caused by wear.
5) To absorb the shock between bearings and other parts and consequently reduce noise.

Types of lubrication system

Various types of lubrication system are

(1) Wet sump lubrication system
   (a) Splash system
   (b) Pressure system
   (c) Semi Pressure system.
(2) Dry sump lubrication system.
(3) Mist lubrication system.

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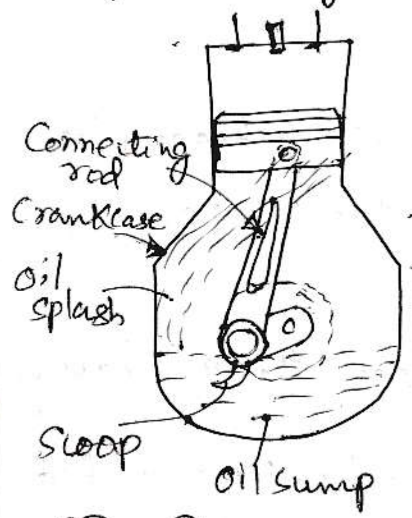
① Wet Sump lubrication System

This system require large capacity oil sump at the base of the crankshaft, from which the oil is drawn by low pressure oil pump and delivers it to various parts. Oil than gradually returns back to the sump after serving the purpose.

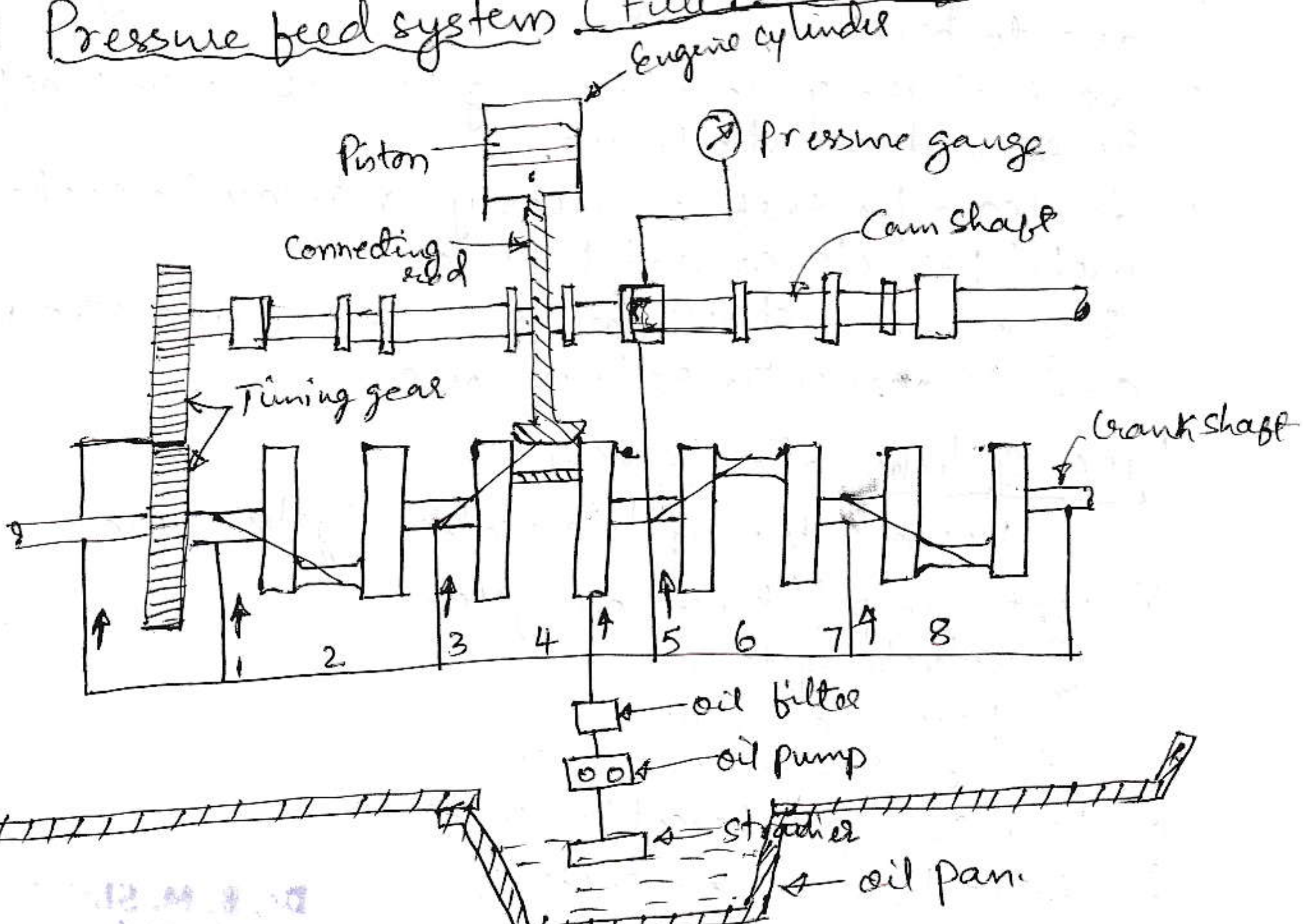
ⓐ Splash system

This system is suitable for low and medium speed engines.



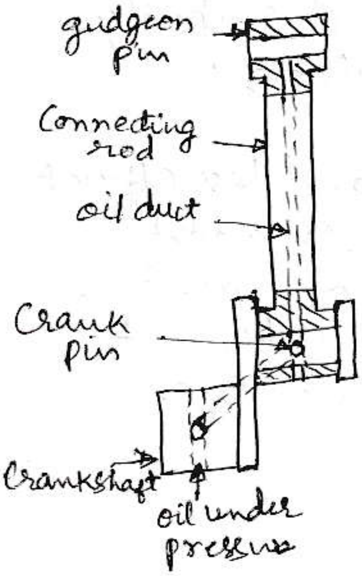
In this system, a scoop at the big end of the connecting rod splashes the lub oil from the oil sump. This causes the ~~be~~lubrication of engine walls, gudgeon pin, crank shaft bearing, connecting rod bearings etc. Surplus oil eventually flows back to the oil sump.

ⓑ Pressure feed system (Full Pressure system)



This system consists of an oil pan, oil pump, strainer, oil filter and oil pipes. The pump pressurises the oil to 1.5 to 4 bar and the oil passes through the filter and various parts through the pipe lines. The used oil again drains back to the oil pan. The pressure gauge is provided to confirm the circulation of oil to all the various parts. This is most effective and positive type of lubrication. A combined splash and pressure feed system is further more effective in IC engines.

c) Semi Pressure lubrication



In this system, oil under pressure is sent to the main bearings only. The system is also incorporated with splash system, which lubricates big end, gudgeon pin bearing, cylinder walls, timing gears and camshaft bearings.

This method is combination of splash and pressure systems. This system is less costly to install as compared to pressure system.

d) Mist lubrication system

This system is used for two stroke cycle engines. Most of these engines are crankcharged i.e they employ crankcase compression and thus, are not suitable for crankcase lubrication. These engines are lubricated by adding 2 to 3 pecent lubricating oil in the fuel tank. The oil and fuel mixture are induced through the carburettor. The gasoline is vapourised and the oil in the form of mist, goes via crankcase into the cylinder. The oil which impinges on the crankcase walls lubricates the connecting rod bearings and rest of the oil which passes on the cylinder during charging and scavenging periods, lubricates the piston, piston rings and the cylinder.

Advantages

1) System is simple
2) Low cost as no oil pump and filter are required.

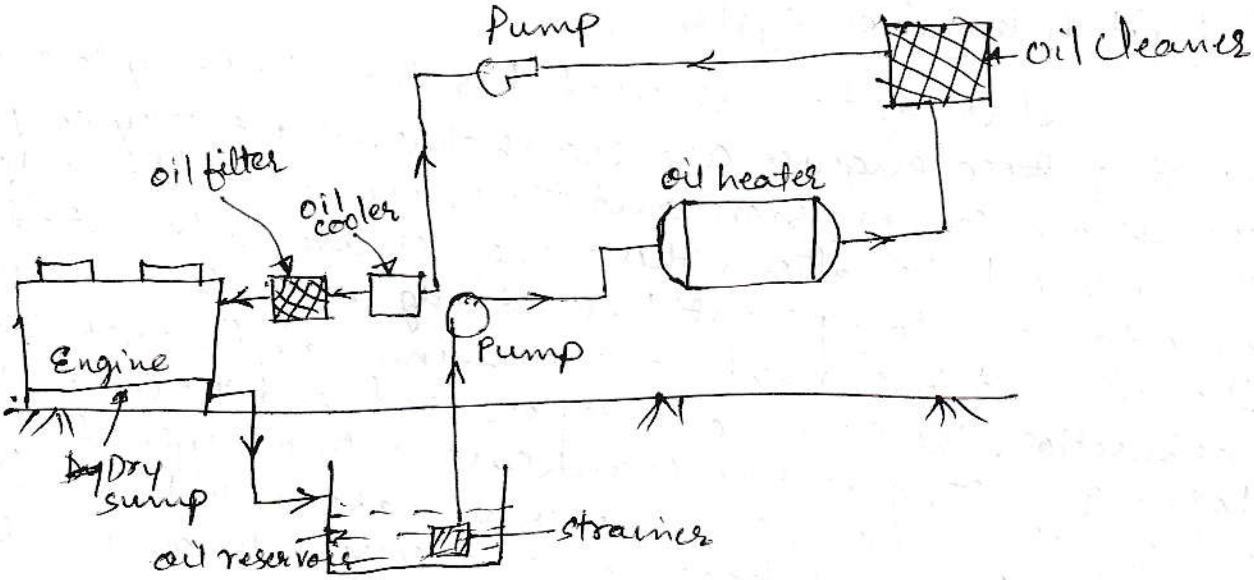
Disadvantages

1) A portion of the lubricating oil invariably burns in the combustion chamber. The oil, when burnt and still worse, when partially burnt in the combustion chamber leads to heavy exhaust emissions and formation of heavy deposits on piston crown, ring grooves and exhaust port which interferes with the efficient engine operation.

2) One main function of lubricating oil is the protection of anti friction bearings etc against corrosion. Since the oil comes in close contact with acidic vapours produced during the combustion process, it rapidly loses its anti-corrosion properties resulting in corrosion damage of bearings.

3) Due to higher exhaust temperature and less efficient scavenging the crank case oil is diluted. In addition some lubricating oil burns in combustion chamber. This results in 5 to 15 percent higher lubricant consumption for two stroke engine of similar size.

3) Dry sump lubrication system



Dry sump lubrication is generally adopted for high capacity engines. In this system no oil is stored in the engine crank case sump, hence it is called as dry sump lubrication system. The used oil from various parts falls into the crank case and is then routed to the oil reservoir. The oil from the reservoir is pumped to a oil cleaner through oil heater in order to reduce the viscosity. The cleaned oil is pumped to an oil cooler and then passed through fine sized oil filter to remove fine sized dust particles from the oil. Finally it is passed to the engine parts.

Main parts of the diesel engine, such as piston-cylinder, crankshaft, gudgeon pin bearings, and crank shaft bearings are to be lubricated using forced feed lubrication.

Reconditioning of lubrication oil

In the lubrication system, the oil carries carbon particles, water and metal scraps. This oil cannot be ~~reuse~~ reused after cooling, unless these impurities are removed from it. For this purpose, filters, centrifugal cleaners or chemical cleaning plants are used. The mechanical type filters used are cloth bags, wooden pads, paper pad and porous material pads. Many a times, the oil from the engine is filtered by passing through metal screen stainers and ultimately cleaning is accomplished by passing the oil through centrifugal cleaners. Before passing through the cleaning system, it is necessary to heat the oil to increase it's fluidity.

Reconditioning of the used oil is carried out in the following steps

1) Collection:- The oil ~~fe~~ with impurities is collected from the engine to a tank.

2) Heating:- The lubricating oil with impurities is heated using exhaust gases, so that its fluidity increases and the cleaning operation becomes easier & faster.

3) Filteration:- All the impurities are removed by passing through mechanical ~~st~~ cleaners. The ~~med~~ oil is first passed through metal screen strainers and then through centrifugal cleaners.

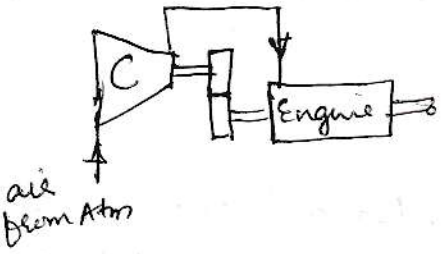
4) Cooling:- The oil is cooled down after passing through heat exchanger. Generally water is circulated.

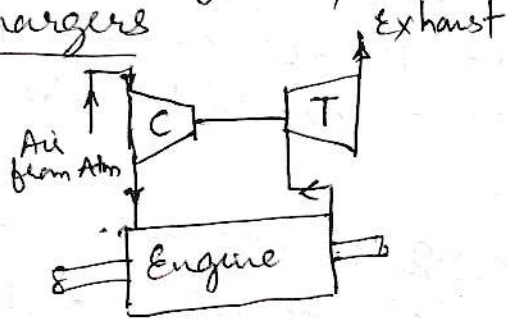
5) Further addition & use:- In this system some oil is lost in cleaning & some oil is lost due to leakages in the lines. Hence, to maintain constant level of oil for lubrication, some quantity of fresh oil is added, each time the purified oil is supplied for reuse.

Supercharging

The term supercharging refers to increasing the air or mixture density by increasing its pressure prior to entering to the engine cylinder.

Mechanical Superchargers





~~Advantages~~ {Objects} of Supercharging

1) To increase power output for a given weight of the engine. This is important in aircraft, ~~and~~ marine and racing car engine.
2) To increase power output for a given size of engine so as to fit into a limited space such as in locomotives & marine engines.
3) To compensate power loss due to high altitudes as in case of aircraft engine.
4) To obtain more power from existing engine

Advantages

1) Increased power output:- A supercharged engine develops about 30 to 50 percent of increased power
2) Fuel economy:- Supercharging helps for complete Combustion of the charge and hence there is no wastage of fuel.
3) Higher efficiency:- The mechanical & thermal efficiency of Supercharged engine is higher compared to naturally aspirated engine.
4) Reduced Noise:- Supercharging helps faster mixing of the fuel with the compressed air thereby reducing the delay time. This reduces the Diesel knock, which is thus main cause of high level combustion noise in diesel engine. The engine runs more smoothly with reduced noise.
5) Reduced engine noise:- For a given output the engine size with a supercharged engine is smaller. Hence it is more compact than naturally run diesel engine.

Supercharging limitations

The power output of an engine that is supercharg-ed is limited by Knocking, thermal loads & mechanical loads.

1) The degree of Supercharging in SI engine is limited by Knocking. Further this knock depends on type of fuel used, Fuel Air ratio, spark advance, valve timing and cooling system etc. Usually the supercharged SI engine uses rich mixture to avoid Knocking and preignition problems. Hence results in higher specific fuel consumption

2) The limit of Supercharging in CI engine is reached by thermal loads. The temperature of the piston and cylinder if very high results in scuffing of piston ring and heavy cylinder liner wear. The load on the bearing increases due to increased pressure in the cylinder

Engine starting systems

Since the diesel engines have a high compression ratio. It is difficult to start them by simple methods. This requires seperate starting systems for diesel engine. The following methods are commonly used for starting syst

1) Compressed air system

The compressed air system is commonly used for starting large diesel engines employed for stationary power plant. Compressed air at about 17 bar supplied from air tank is admitted to engine. In multicylinder engine the compressed air enters one cylinder and forces down the piston, in the mean time some other piston performs suction and some compression stroke. With few suction and compression strokes, fuel injection takes place and engine starts and slowly gains momentum to reach its full speed.

2) ~~Use of~~ Electric motor starting system or Self starters

In this method, an electric motor is connected to the engine crank shaft and operated by batteries. The starter motor runs till engine starts properly, and then, it is disconnected properly. This method is simple & faster

3) <u>Starting by an auxiliary engine (Generally petrol driven)</u>

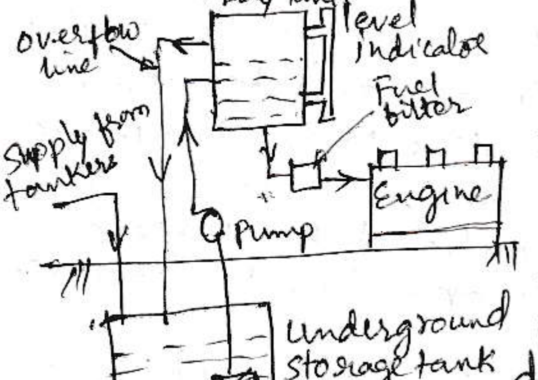
In this method, a small petrol engine is mounted close to the main engine and drives the latter through clutch and gears. The clutch is first disengaged and the petrol engine is started by hand or by self starter motor. Clutch is then gradually engaged, so that the Diesel engine is coupled and the diesel engine starts. Clutch is automatically disengaged when the main engine starts and reaches its full speed.

<u>Diesel storage and supply systems</u>

The Diesel storage and supply system used depends upon the plant size, layout and space availability. There are two types of fuel supply system.

1) <u>Suction system</u>:- This system is suitable for small capacity plants. In this system the fuel is stored in a service tank below or in the engine level. The oil is drawn by suction pump driven by the engine crankshaft. The pump delivers constant volume of fuel to the engine and hence an overflow line is connected back to the supply tank, to take care of excess flow that may occure during low demand conditions.

2) <u>Transfer system</u>:- This system is suitable for large and medium capacity plants.



In this system, the diesel oil is supplied from oil tankers to the large storage tank located below the ground level. The oil from the underground tank is supplied to an overhead tank termed as day tank by pump, which supplies ~~to~~ fuel to the engine daily. The day tank is fitted with fuel indicator. The fuel from the day tank enters the engine by gravity. Filters are provided to clean the fuel entering the engine.

The main tank can also be located above the ground level, which makes the maintenance easy, also any leakage can be detected quickly. But the underground tanks have the advantage of reduced risks of fire hazards and space utilization.

In some cases the oil from the main tank is heated by supply hot water through the jacket provided. Heating the fuel before being supplied to the engine improve the combustion efficiency.

(Merits) Advantages of underground storage tanks

1) Economy in space utilization.
2) Free from fire hazards.
3) Easy unloading from supply tankers to the underground tanks.
4) Plant looks very compact.

Disadvantages (Demerits)

1) Periodical cleaning of tank is difficult.
2) Fuel leakages can't be detected easily.
3) Repair and maintanance is a problem.
4) Fuel pumps are essential to raise the fuel from underground.
5) Tanks get corroded faster under the ground. Hence, life is less.

Advantages (Merits) of overhead storage tanks:

1) Cleaning the tanks is easier.
2) Fuel leakages can be detected easily.
3) Repair and maintanance is simple.
4) Life of tank is more.

Disadvantages (Demerits) :

1.) Needs extra space for installation above the ground.

2) changes of fire hazards are more.

3.) Unloading from tankers to over head storage tanks ~~to~~ needs pumps.

4) Strong construction is essential to locate the overhead tank.

Unit 1
Steam Power Plant

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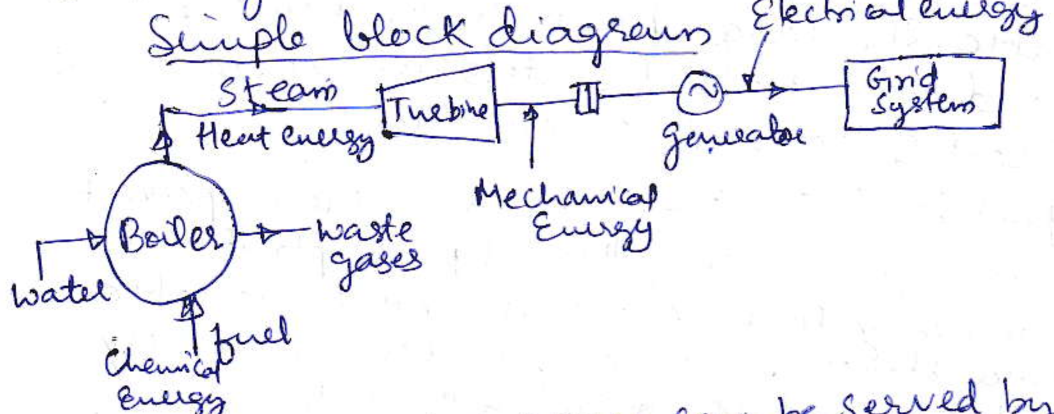
A steam power plant converts the chemical energy of fossile fuels (coal, oil, gas) into heat energy in the boiler, which intern converted into mechanical energy in the turbine by expansion. The mechanical energy of turbine is converted into electrical energy in the generator.

Simple block diagram



The following purposes can be served by steam power plant.

1) To produce electricity
2) To produce steam for industrial purposes besides producing electrical energy. The steam produced may be used for varying purposes in industries such as Textiles, food manufacturing, paper mills, sugar mills and refineries etc.

Selection of site for steam power plant

The following points should be taken into considerations while selecting the site for steam power station.

1) Availability of raw material :- Modern steam power stations using coal or oil as fuel requires huge quantity of it per annum. A thermal power plant of 400 MW capacity requires 5000 to 6000 tonnes of coal per day. Therefore it is necessary to locate the plant as far as possible near the coalfields in order to save transportation costs.

2) Nature of Land:- The type of land to be selected should have good bearing as it has to withstand the dead load of the plant and the forces transmitted to the foundation due to the machine operations. The minimum bearing capacity of the land should be 1 MN/m² (10 bar).

3) Cost of land:- Considerable area is required for the power stations. The cost of the land should be reasonable. The large plants in the heart of the cities and near the load centres are not economical as the cost of the land is very high.

4) Transport facilities:- This is another important consideration in locating thermal power plant. It is always necessary to have a railway line available near power station for bringing in heavy machinery for installation and for bringing the coal.

5) Availability of labour:- During construction of the plant enough labour is required. The labour should be easily available at the proposed site at cheap rate.

6) Ash disposal facilities:- The ash handling problem is more serious than coal handling because it comes out in hot condition and it is highly corrosive. It's effect on atmospheric pollution are serious as the human health is concerned. Therefore, there must be sufficient space to dispose off large quantity of ash.

In a power station of 400 MW capacity 10 hectares area is required per year if the ash is dumped to a height of 6.5 meters.

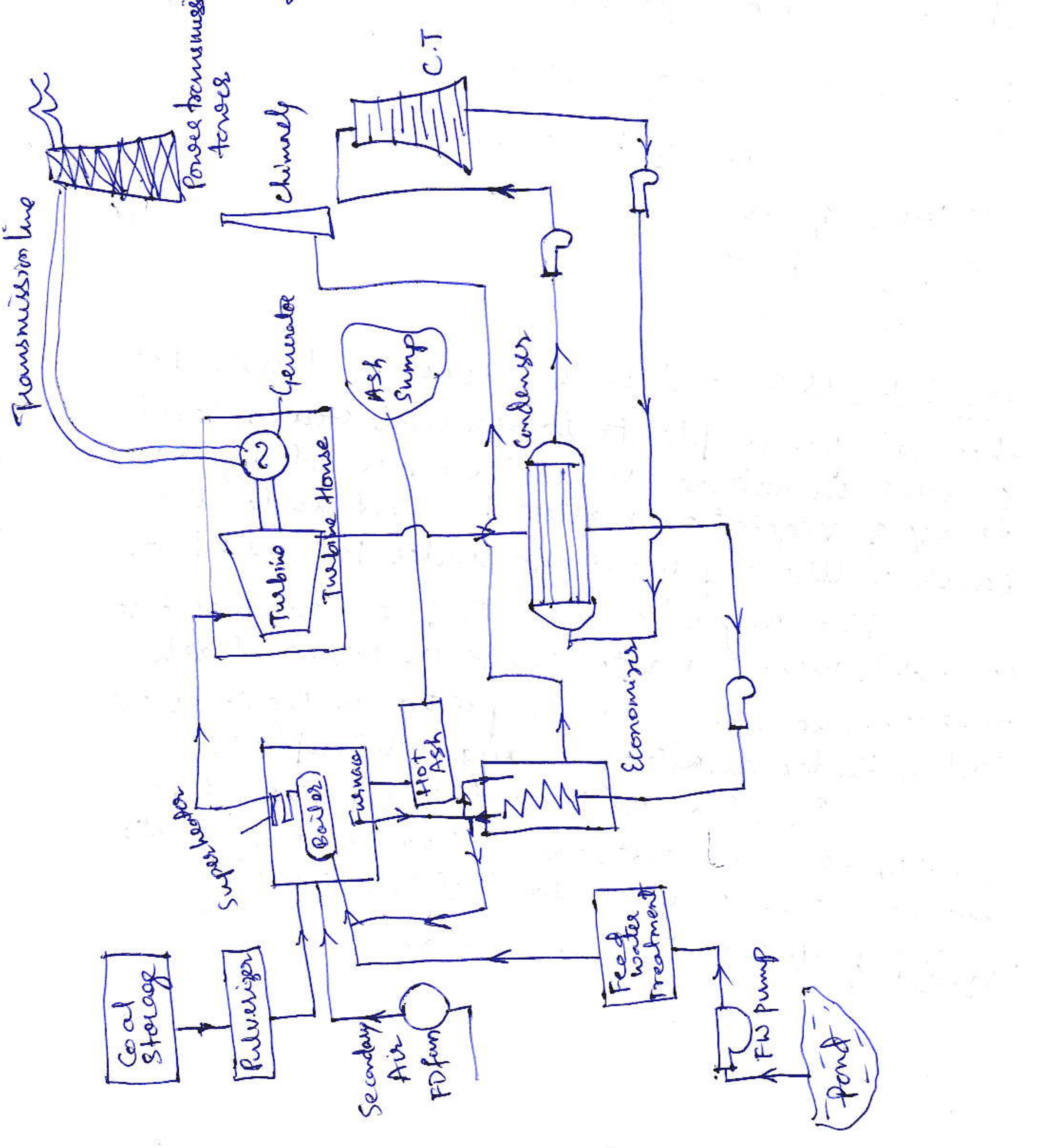
7) Availability of water:- Large quantities of water are required for condenser, for disposal of ash and as feed water to the boiler and drinking water for working staff. It is therefore necessary to locate the power plant near the water source.

8) Space requirement:- The space and building requirements by the power plant is another important point to be considered. The average land requirement is 3 to 5 acres per MW capacity which includes space required for coal storage, ash

disposal, staff colony, market facility and space required for whole machinery.
(buildings - 10%, coal storage - 33%, cooling tower - 27% (if any) 7% for switch yard and 23% for other purpose)

9) Public problems:- The proposed site should be far away from the towns to avoid the nuisance from the smoke, fly ash and heat discharged from the power plant.

Layout of Steam power plant



The above figure shows the layout of TPP

(a) Turbine generator
(b) Furnace boiler
(c) Fuel handling system
(d) Ash handling system
(e) Draught system.
(f) Condensing system.
(g) Water cooling system.
(h) Lubrication system.

Fuels used in Steam Generation

Three types of fuels are

1) Solid fuels
2) Liquid fuels
3) gaseous fuels.

Solid fuels :- Coal is the major fuel used for thermal power plants to generate steam. Coal occurres in nature, which was formed by the decay of vegetation matters burried under the earth millions of years ago under pressure & heat.

The major constituents of coal are moisture (5-40%), volatile matter about 40-50%. and ash 20-50%. The chemical composition in the coal are Carbon, Hydrogen, nitrogen, oxygen & Sulphur.

Based on the present consumption, it is roughly estimated that, the coal will last for another 300 years and 30 years for high grade coal.

Liquid fuels :- (20 years) oil gas - 60 years)

Equipments for burning coal in lump form

Lump → A small piece of something solid without particular shape.

~~Hee~~ Coal burning Methods

The efficient combustion of fuel in the combustion chamber and efficient transfer of heat energy to the water for steam generation are essential for the economic working of the power plant. The two common methods used for burning coal are stroker firing and pulverised fuel firing. The stroker firing method is used for solid fuels and pulverised fuel firing method is used for pulverised coal.

The selection of firing method for a particular power plant depends upon the following factors

1. The characteristics of available coal.
2. Capacity of the plant.
3. Load factor of the power plant.
4. Nature of load fluctuation

Classification of firing methods (combustion system) for coal burning are

(A) Solid fuel firing:-

- (a) Hand fired
- (b) Stroker feed
- (c) Pulverised fuel

Again stroker firing method is subdivided into

(a) Over feed stroker
1) Chain grate
2) Travelling grate
3) Spreader type

b) Underfeed stroker
1) Single retort
2) Multi retort

And pulverised coal firing method is classified as

1) Unit system
2) Central system. or Bin system.

The hand firing system is the simplest method of fuel firing, but it cannot be used in modern power plants as it gives lower combustion efficiency, it doesnot respond quickly to fluctuating loads and control of draught is difficult.

1) Mechanical stroker firing

Stroker:- It is a power operated fuel feeding mechanism and grate.

Advantages of stroker firing

1) cheaper grade fuel can be used
2) Higher efficiency can be attained
3) Greater flexibity of operations assured.
4) Less smoke produced.
5) Less building space is required.
6) Can be used for small or large boiler units
7) Maintenance charges are reasonable.
8) Capital investment as compared to pulverised fuel system is low.

Disadvantages

1) Construction is complicated
2) There is ~~excess~~ excessive wear of moving parts due to abrassive action of coal

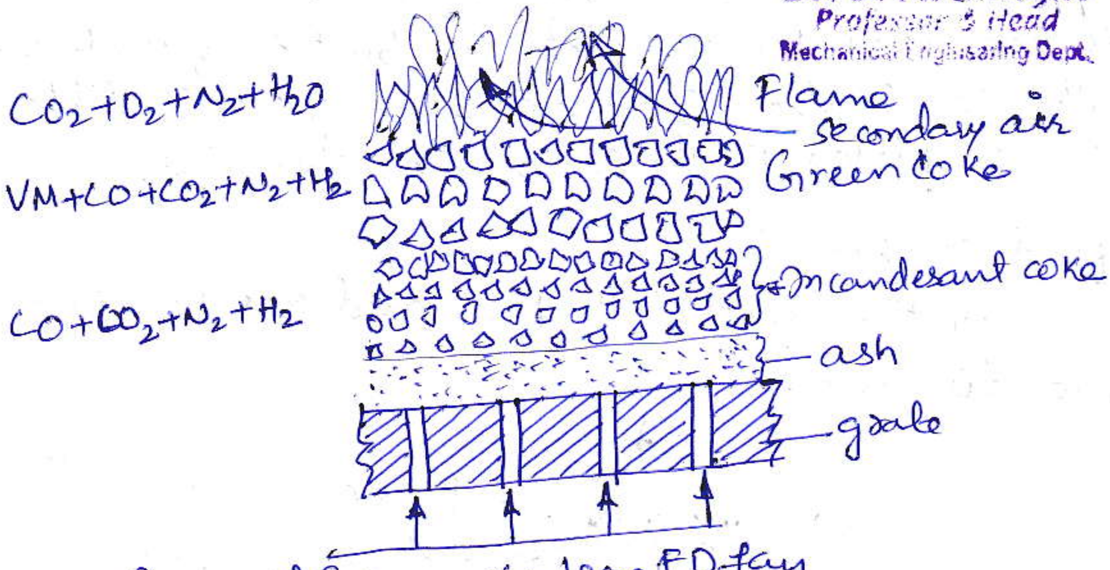
Classification of Mechanical strokes firing

1) Overfeed stroker
2) Underfeed stroker.

In case of overfeed strokers, the coal is fed into the grate above the point of air admission. and in case of underfeed strokers, the coal is fed into the furnace below the point of air admission.

Overfeed strokes

In case of overfeed stroker, the coal is fed on to the grate above the point of admission of air.



Pressurised Primary air from FD fan

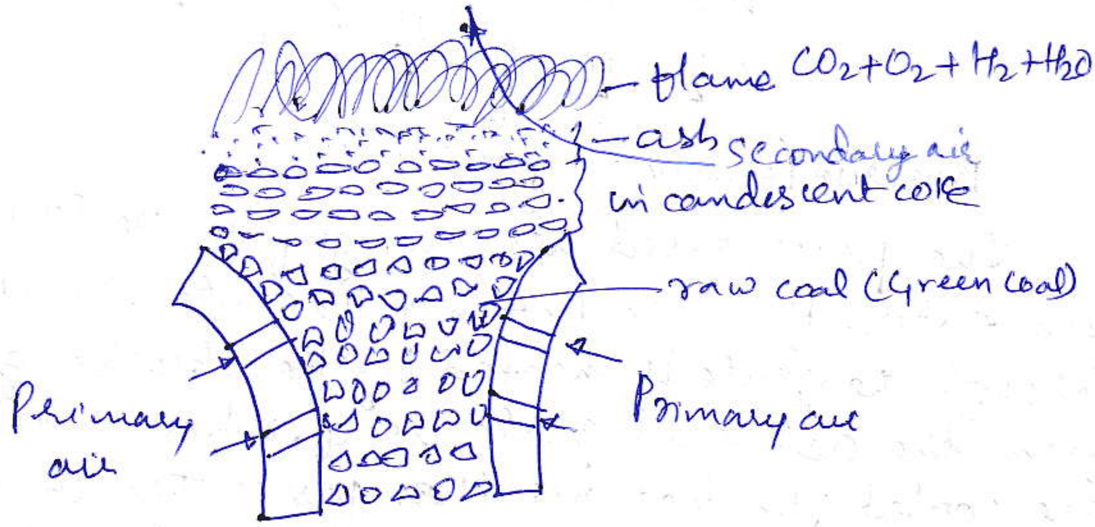
The pressurised air coming from the Forced draft fan enters from the bottom of the grate. The air passing through the grate is heated by absorbing the heat from the ash and grate itself, where as ash and grate are cooled. The hot air than passes through a bed of incandescent coke, where the O_2 reacts with carbon to form CO_2. The rate of carbon-oxidation in this part of fuel depends entirely on the rate of air supply. Generally for the fuel bed of 8 cm deep, all the oxygen present in the air dissappears in the incandescent zone. The water vapour carried with air reacts with carbon in incandescent zone and forms CO, CO_2 & H_2 and part of CO_2 formed reacts with C and forms CO. The gas leaving the incandescent zone of fuel bed consists of N_2, CO_2, CO, H_2 & H_2O.

The raw coal is continuously supplied on the surface of the bed. Here it losses its volatile matter by distillation. The heat required for the distillation is given by incandescent coke below the fresh fuel, hot gases diffusing through the bed and hot gases and flame in the furnace. The ignition zone lies directly below the raw fuel.

The gases leaving the upper surface of the bed contains combustible volatile matter formed from the raw fuel, N_2, CO_2, CO, H_2 & H_2O. Additional secondary air is supplied at a very high speed to create turbulence which is required for complete combustion of unburned gases. The combustion of the remaining combustible gases is completed in the combustion chamber.

Underfeed strokers

In this method the fuel and air moves in the same direction.



This stroker is suitable for burning bituminous & sub bituminous coals. Primary Air entering through the holes of the grate comes in contact with green coal. Then air passes through the incandescent coke where it reacts with carbon in coke to form CO_2 and H_2O moisture in the air reacts to release CO_2, CO, & H_2 while these gases passes over the ash bed. Secondary air is supplied for complete combustion

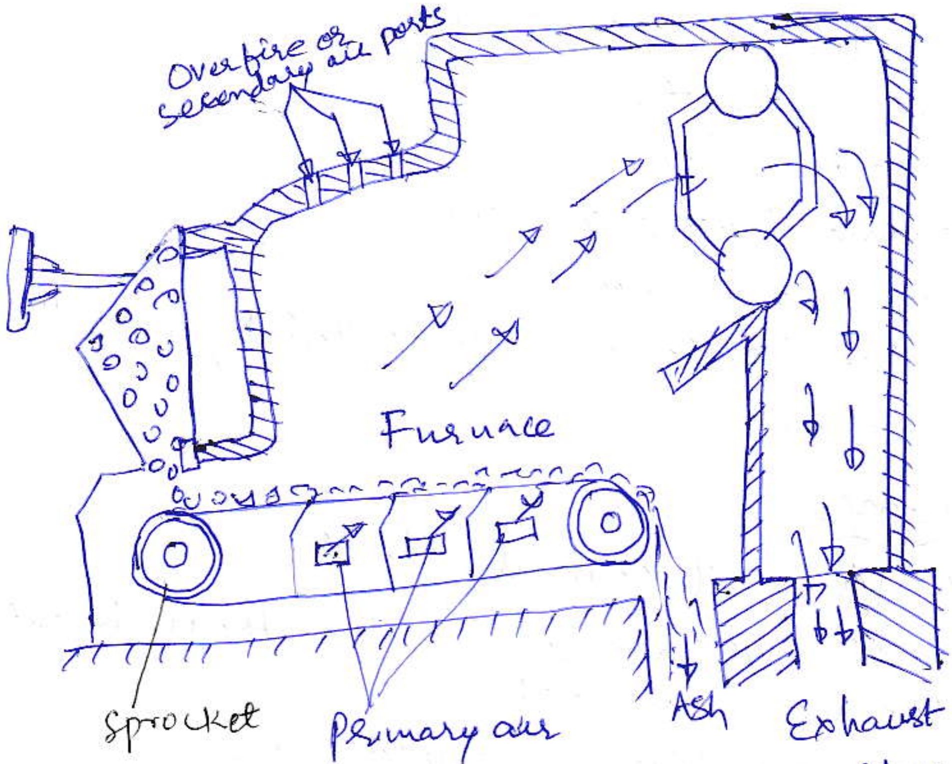
Types of overfeed strokers

The following are the types of overfeed strokers.

1) Conveyer strokers
   (a) Chain grate strokes
   (b) Travelling grate strokes
2) Spreader stroker

(a) Chain and Travelling grate stroker

These types of strokers are used for large capacity boiler installations, where coal is burnt without pulverisation.



The chain grate stroker consists of endless chain which forms a support for the fuel bed. The chain travells over two sprockets wheels one at the front and other at the rear of the furnace. The front sprocket is connected to a variable speed mechanisms. The speed of the stroker is 15cm to 50cm per minute. The coal is fed at the front through hopper and is carried by the chain to the other end, hence into the furnace. The air necessary for combustion is admitted from the underside of the grate. The secondary air is supplied through the openings in the top of the roof.

The rate of fuel supplied to the grate and hence heat to the boiler can be controlled by two means. The first method is to control the depth of the coal bed on the grate by controlling the feed to the hopper. In the second method, the speed of the chain grate can be adjusted to meet the boiler operation requirements

This type is best suited for burning non-coking coals. The rate of burning with this stroker is 200 to 300 Kg per m^2 per hour when forced draught is used.

Advantages of chain grate stroker

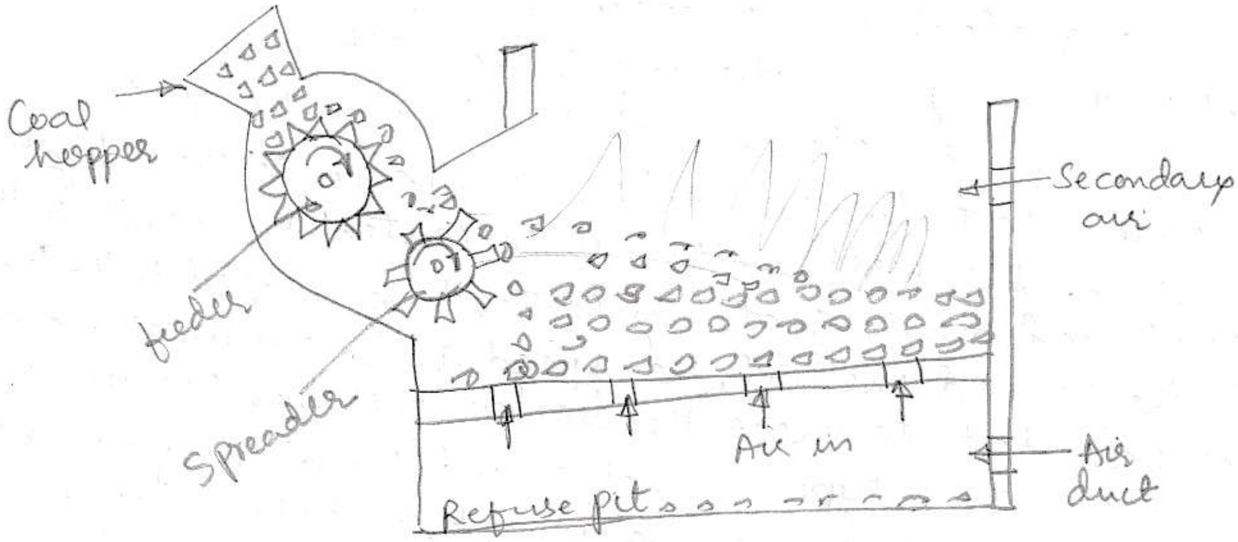
1) Simple in construction
2) Initial cost is low
3) Maintenance charges are low
4) self cleaning stroker
5) Heat release rate can be controlled by controlling the speed of chain.

Disadvantages

1) Suitable for small capacity plants
2) There is always some loss of coal as the unburnt coal may also move with ash.
3) The clinker troubles are very common.

In travelling grate stroker, the chain grate is replaced by grate bars that supports the fuel. The grate is inclined towards the inlet of the furnace. The movement is accomplished & controlled by the vibration of the grate. The air supply is similar to the chain grate stroker.

b) Spreader or sprinkler stroker



In this type of stroker, the coal is not fed into the furnace by means of grate. The function of the grate is only to support a bed of ash and move it out of furnace. The coal from the hopper is feed on the rotating feeder which inturn feeds the coal to the spreader, which inturn feeds the coal according to the requirements.

Feeder is a rotating drum fitted with blades on its periphery. The feeder continuously supplies the coal to the spreader, which is a fast rotating drum with blades, which inturn distributes ~~the~~ and feeds the coal on the grate.

The rate of fuel feed and heat supplied to the boiler can be controlled by controlling the feed to the hopper or by controlling the spreader speed

The air supplied by FD fan through the openings provided in the grate. The secondary air is supplied through the nozzle. The secondary air creates high turbulence and completes the combustion of volatile matter and fine particals of coal.

The selection of coal size used is very important in the spreader. The coal size used should be in the range of 6 cm to 36 cm. The heat release rate of 40×10^6 KJ/m²-hr is possible with stationary grate (Generally used upto 10MW plant capacity) and 80×10^6 KJ/m²-hr is possible with moving grate (used between 10MW to 30MW plant capacity)

Spreader stroker can burn any type of coal.

Advantages of spreader stroker

1) A wide veriety of coal can be burnt.
2) This stroker is simple to operate
3) The use of high ~~p~~ temperature preheated air is possible.
4) Valatile matter can be easily burnt.
5) It can respond quickly to the load variations.

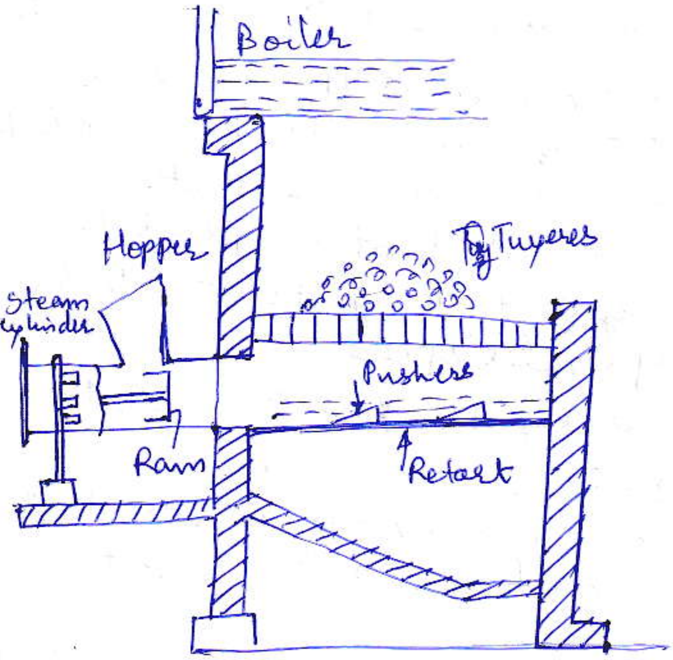
Disadvantages

1) It is not possible to burn varying sizes of coal & only crush sized coals are used.
2) Fly ash is much more
3) No remedy for clinker problems
4) Unburnt coal particals may move through the flue gas hence reduce combustion efficiency.

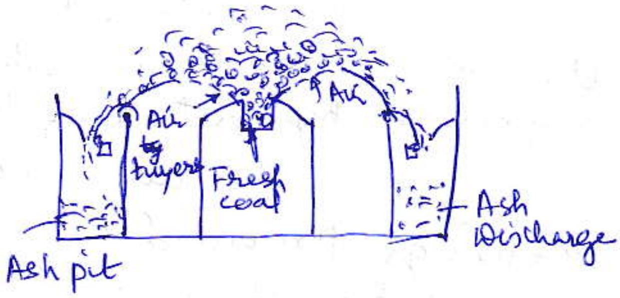
Under feed strokers

The under feed strokers fall into two groups
1) Single Retort stroker.
2) Multi Retort stroker.

1) Single retort stroker

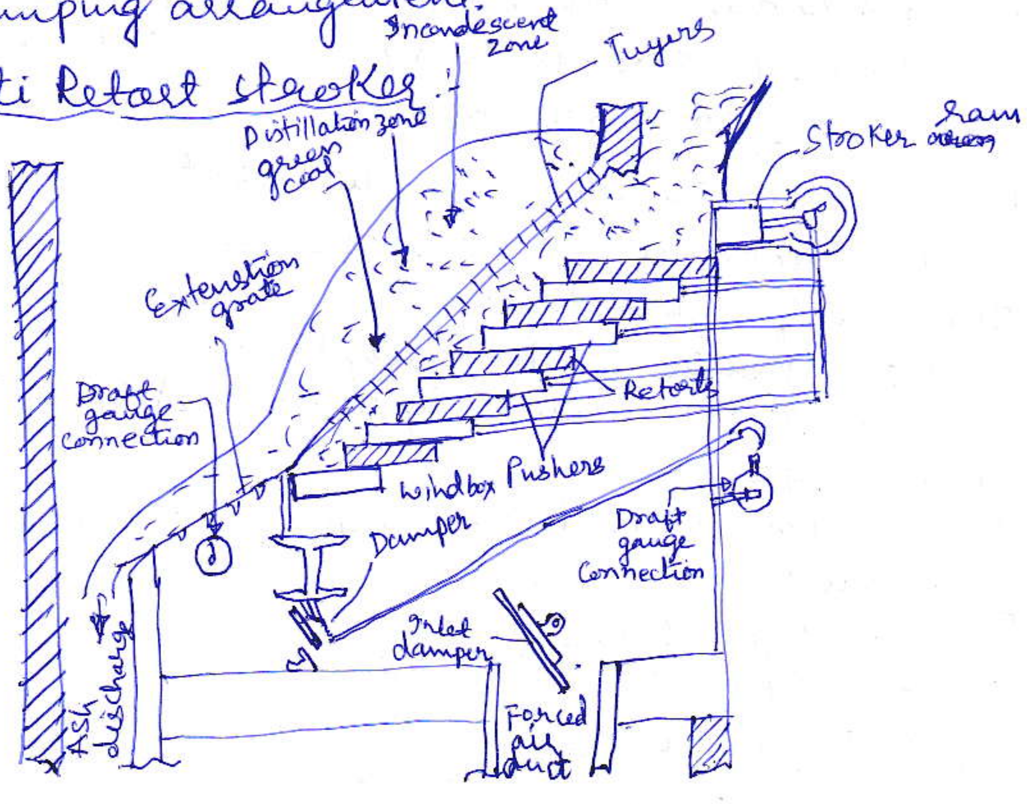


In this method the fuel is burnt on the retort.



The fuel is placed in the large hopper on the front of the furnace, and then it is further fed by reciprocating rams on to the retort. The air is supplied through the tuyeres provided along the upper edge of the grate. The ash and clinkers are collected on the ash plate provided with dumping arrangement.

2) Multi Retort stroker



It consists of a series of retorts, tuyers and pushers. Each retort is fitted with a reciprocating ram for feeding and pusher plate for uniform distribution of coal. The coal falling from hopper is pushed ~~forward~~ forward during the ~~~~ inward stroke of the stroker ram. Then the distributing rams (pushers) push the entire coal down the length of the stroker. The ash formed is collected at the other end as shown in the figure. The primary air is supplied to the fuel bed from the main wind box situated below the stroker. The partly burnt coal moves onto the extension grate, wind from main wind box is supplied to the thinner fuel bed on the extension grate. The quantity of air supplied is regulated by the damper. The ash formed from all the retorts fall into the ashpit.

Combustion control in introduced into the stroker drive either by varying the ram stroke or by changing the rate of reciprocation

~~Ad~~ Advantages

1) High thermal efficiency as compared to chain grate.
2) Combustion rate is considerably higher
3) The grate is self cleaning.
4) Different varieties of coal can be used.
5) This stroker respond quickly to the varying load.
6) Smokeless operation is possible even at light load.

Disadvantages

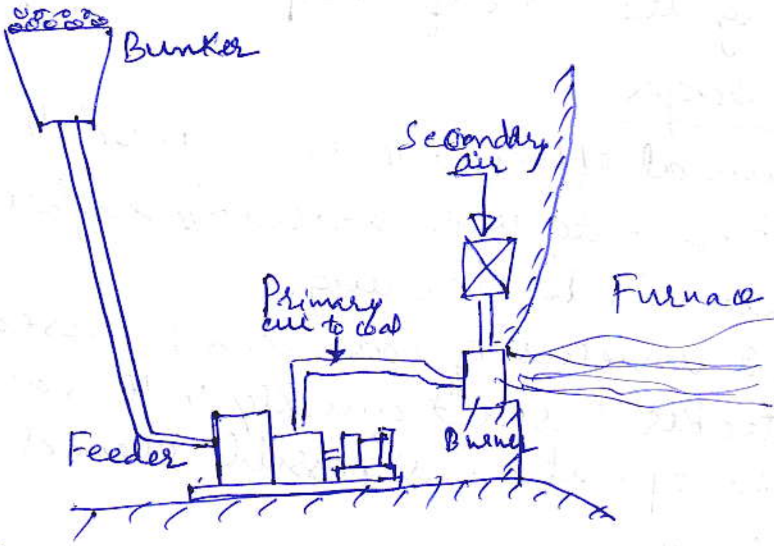
1) High initial cost
2) Require large building space
3) The clinker troubles are usually present.
4) Low grade fuels with high ash content can not be burnt economically.
5) The operation and maintenance is very high

Pulverised coal firing

In pulverised coal firing system, the coal is first crushed to a fine powder with the help of grinding mill and then injected into the combustion chamber with the help of hot air current. The amount of air required for combustion is supplied seperatly to the combustion chamber. The resulting turbulence in the combustion chamber helps for uniform mixing of fuel and air.

The amount of air used to carry the pulverised coal and to dry it before entering the combustion chamber is known as primary air. and the amount of air is supplied seperatly for completing the combustion is known as Secondary air.

The efficiency of the pulverised fuel firing mostly depends upon the size of the powder. The fineness of the coal should be such that 70% of it should pass through a 200 mesh.



Advantages

1) Any grade coal can be used since coal is powdered before use
2) The rate of fuel feed can be regulated properly resulting in fuel economy.
3) Since there is almost complete combustion of the fuel there is increased rate of evaporation & hence higher boiler efficiency.
4) Greater capacity to meet peak load.
5) The system is practically free from sagging & clinkering troubles

6) Practically no ash handling problems
7) This system works successfully in combination with gas and oil.
8) Much small quantity of air is required as compared to that of stroker firing
9) The external heating surfaces are free from corrosion
10) It is possible use highly preheated secondary air about 350°c which helps for rapid propagation of flame.
11) The furnace volume required is considerably less

Disadvantages

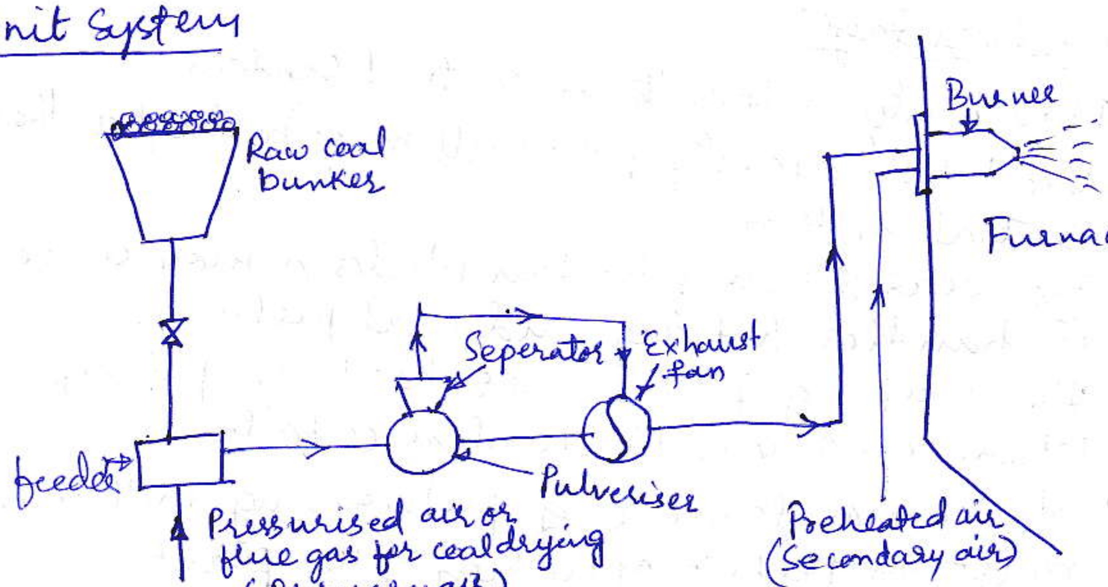
1) High initial cost.
2) Lot of fly ash in the exhaust which makes the removing of fine dust uneconomical.
3) The possibility of explosion is more as coal burns like gas.
4) The maintenance of furnace brick work is costly.
5) Skilled operators are required.
6) Seperate coal preperation plant is necessary.

Types of pulverised coal Handling

Pulverised fuel firing plants are divided into two types

1) Unit systems
2) Central system.

Unit system



Most pulverised coal plants now being installed with unit Pulveriser

The unit system is so called because each burner and pulveriser constitute a unit.

The raw coal is supplied to the bunker, where it is crushed to the required sizes. The crushed coal is then fed to the pulverising mill through the feeder at the required rate, depending upon the the combustion requirements. Hot gases are passed through the feeder to dry the coal. The dried coal is pulverised in the mill and it is carried to the burner. An Induced draft fan is used at the pulveriser to carry the powdered coal to the burner. A seperator is provided to seperate the grains of bigger size from the powder and returned back to the pulveriser for further crushing. The secondary air is supplied seperately to the burner for complete combustion.

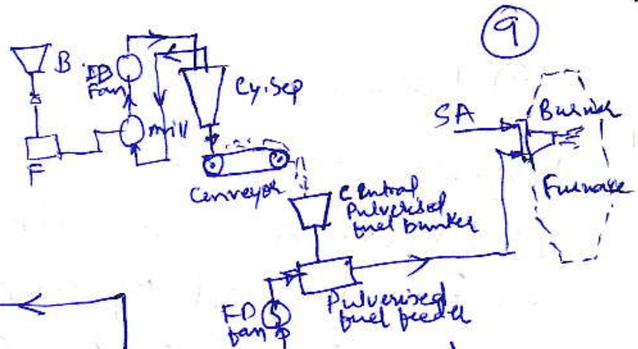
Advantages

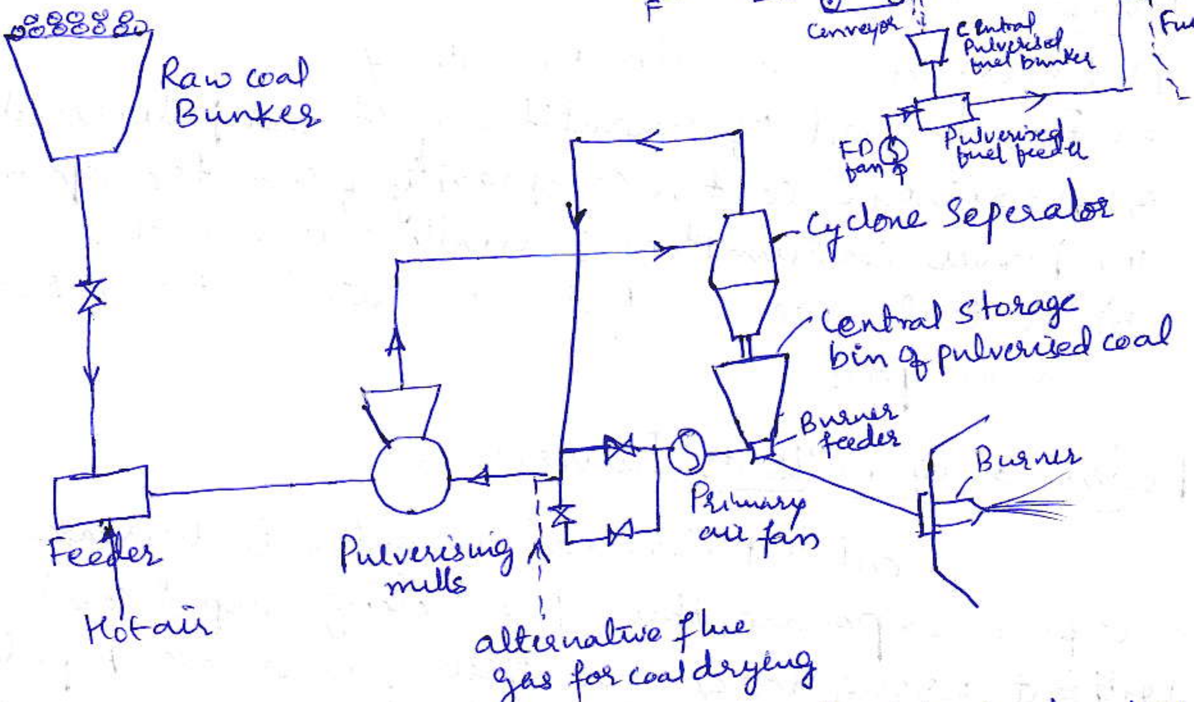
1) The layout is simple and permits easy operation.
2) It is cheaper than central system.
3) Less space is required.
4) It allows direct control of combustion from the pulveriser.
5) Maintenance is less
6) There is no complex transportation system.
7) The unit system may run without drying as compared to central system.

Disadvantages

1) Flexibility is less than central system.
2) The total capacity of the mill must be higher than central system
3) The wear & tear of the fan blades is more since it handles hot air and coal particles.
4) The working of the burner has to be put-off whenever any of the auxiliaries fail.
5) Strict maintenance of pulverising mill is a must for perfect operation of the plant.

Central or Bin Systems





The raw coal is supplied to the bunker where it is crushed to the required sizes. The crushed coal is dried using flue gases and is fed to the pulverisers. The pulverised coal from the pulverising mill is passed to the cyclone seperator, where over sized coal particles are seperated and returned back to the pulverising mill for further crushing. The pulverised coal is then transfered from seperator to central storage bin. The pressurised air from the forced draft fan, supplies the stored coal to the burner. This air not only carries the fuel, but also acts as a primary air for combustion of fuel. The secondary air is supplied to the burner seperatly for complete combustion.

Advantages

1) Offers good control of coal fineness.
2) Less labour is required.
3) Power consumption per tonne of coal handled is low.
4) Burners can be operated independently of the operation of coal preperation plant.
5) The fan wear is less as it handles only natural air.
6) Central system is highly flexible and hence can meet any quick changes in the demand.
7) Coal size can be controlled efficiently
8) There is always some coal is reserved & also available if mill fails

9) The operation of the boiler is unobstructed.

Disadvantages

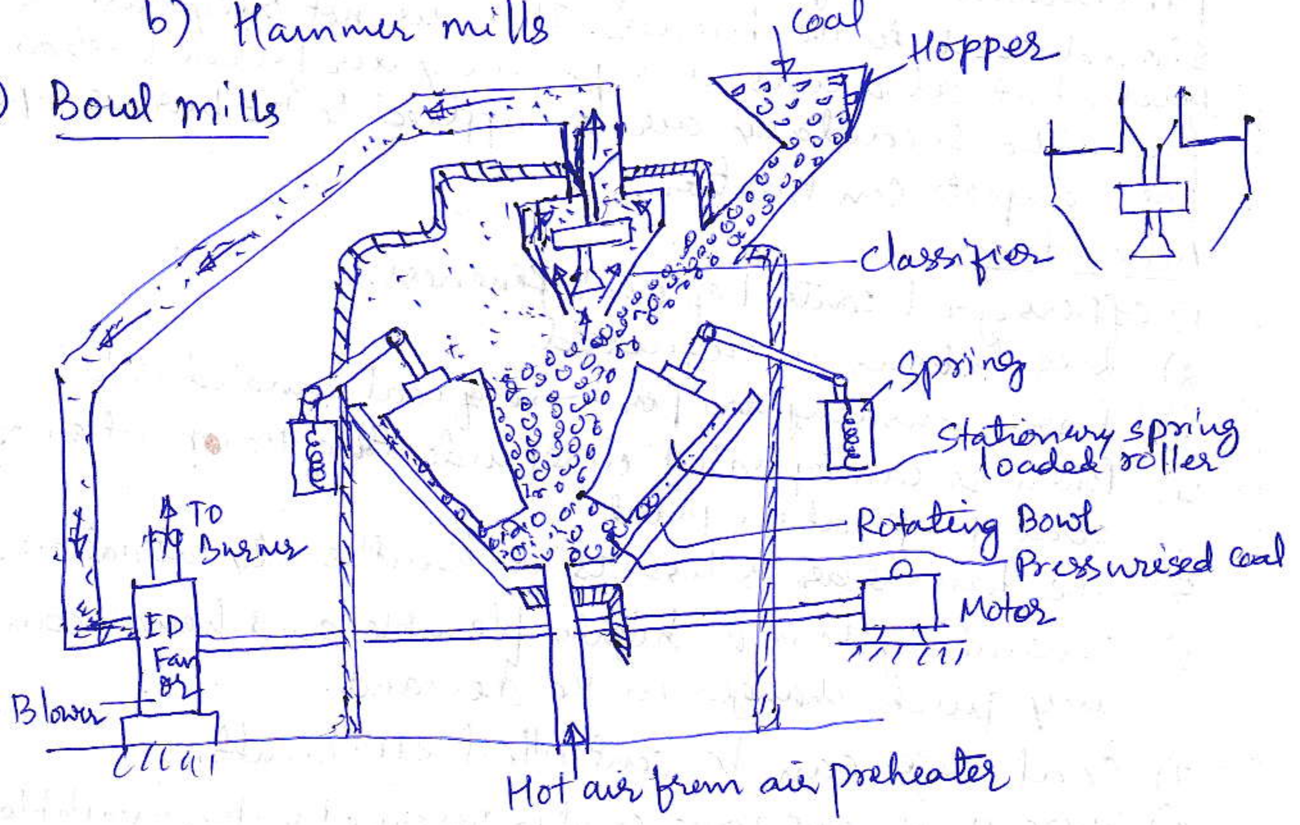
1) Driers are usually necessary
2) Fire hazard of quantities of stored pulverised coal.
3) Additional cost & complexity of coal transportation system
4) Power consumption of auxiliaries is high.
5) Central system is higher in initial cost and requires more space.

Pulverising mills or Pulverisers

Coal is pulverised in order to increase its surface exposure, thus promoting rapid combustion without using large quantities of excess air. A pulveriser is the most important part of the pulverised coal system. Pulverisers are also sometimes called as mills. Pulverisers are classified as

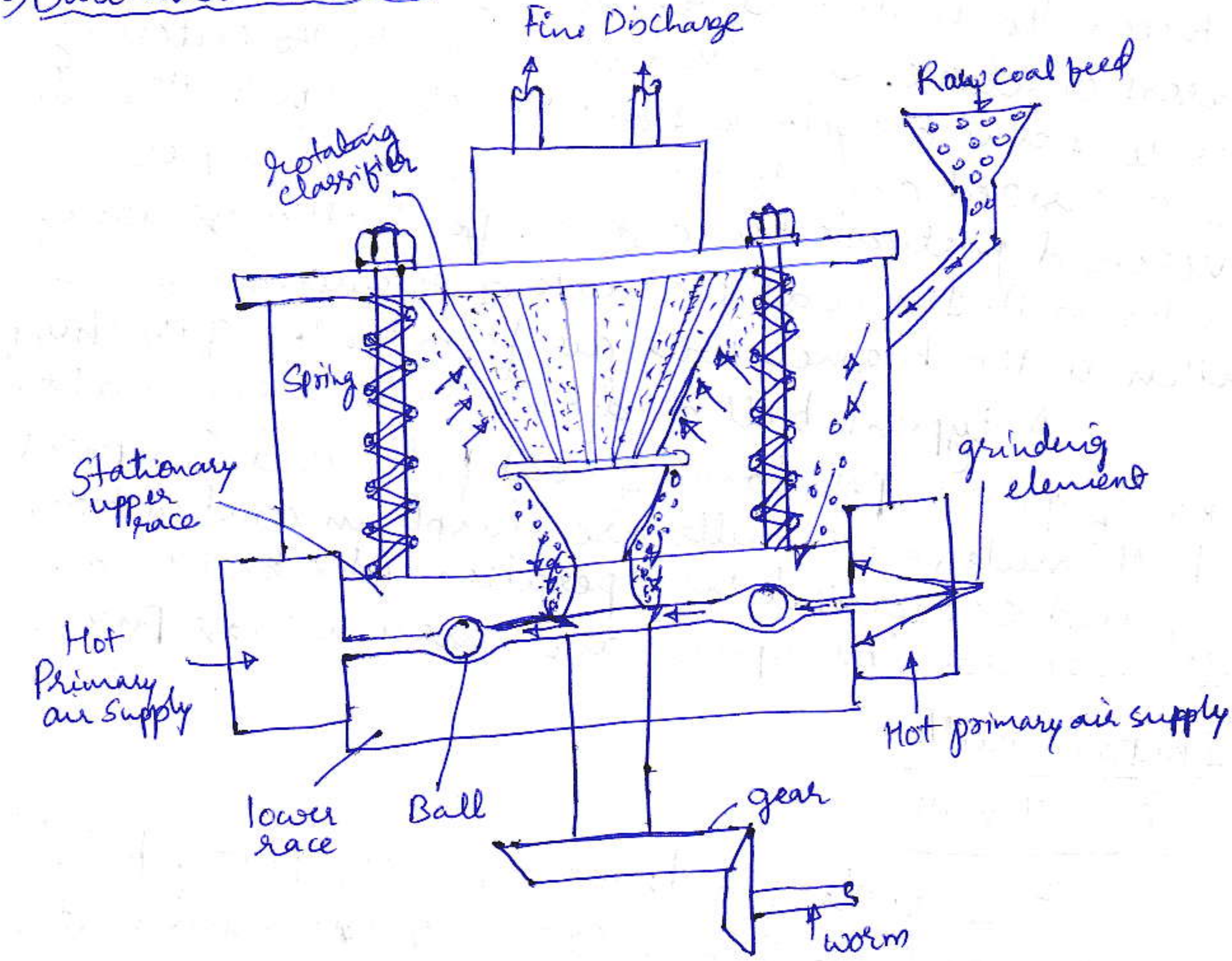
1. Attrition mills
   a) Bowl mill
   b) Ball and race mills
2. Impact mills
   a) Ball mills
   b) Hammer mills

1) Bowl mills



The arrangement of bowl mill is shown in the fig. This pulveriser consists of a stationary rollers and a power driven bowl in which pulverization takes place as coal passes between the sides of bowl and the rollers. A primary air induced draft fan draws the stream of heated air through the mill, carrying pulverised coal into a stationary classifier located at the top of the pulveriser. The classifier returns the coarse particles of coal to the bowl for further grinding through the centre cone of the classifier. The coal pulverised to the desired fineness is carried to the burner through the fan. The impurities in coal containing heavy particles are thrown over the side by centrifugal force as they enter the rotating bowl.

b) Ball and Race mill



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Mechanical Engineering Dept.

This is also known as contact mill which consists of two elements which have rolling action with respect to each other. The coal is passed between the rotating elements again & again until it has been pulverised to the desired degree of fineness.

The coal is crushed between two moving surfaces. The balls and races. The upper stationary race and lower rotating race driven by worm & gear, holds the balls between them. The coal is supplied through the rotating table feeder at the upper right to fall on the inner side of the races. The moving balls and races catches the coal between them to crush it to a powder. Springs hold down the upper stationary race and adjust the force needed to crush.

Hot air is supplied to the mill through the annular space surrounding the races by the forced draft fan. The air picks up the coal dust as it flows between the balls and races and enters into the classifier above. The fixed vanes make the entering air to form a cyclonic flow which helps to through the oversized coal to the walls of the classifier. The oversized particals slide down for further grinding in the mill. The coal particals of required size are taken to the burner with air from the top of the classifier.

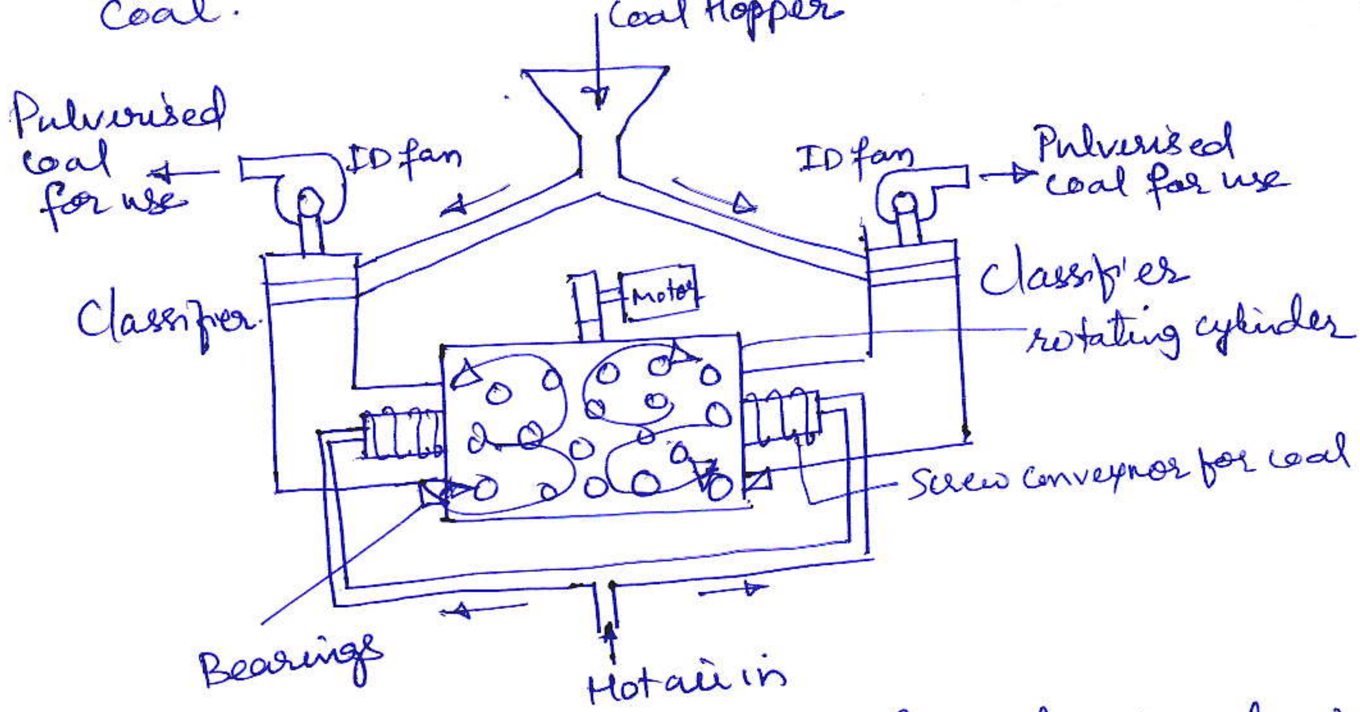
A typical ball and race mill consumes about 15 KW of power per tonne of coal pulverised. Compared to ball mills, such mills are simple in construction, easy and economical for operation. Also ball & race mill requires less space and consumes less power.

2) Impact mills

(a) Ball mills

It consists of a large cylinder partly filled various sized steel balls (2.5cm to 5 cm in diameter)

The coal of 6mm size is fed into the cylinder and mixes with these balls. The cylinder is rotated at a speed of 130 m/min (peripheral velocity) & pulverization takes place as a result of action between balls and coal.



The mill consists of coal feeder, pulveriser, classifier and exhauster. The feeders supply the coal to the classifiers and then is passed through the pulveriser with the help of screw conveyor. The hot air from the preheater is introduced in the pulveriser. These streams of air peak up the pulverised coal and pass through the classifier. The oversized particles are thrown out of the air stream in the classifier back to the pulveriser for further crushing and fine coal is passed to the burner through the exhaust fan.

A ball mill capable of pulverising 10 tonnes of coal per hour containing 4% moisture requires 28 tonnes of steel balls and consumes 20 to 25 KW-hr energy per ton of coal.

Hammer mills or Impact mills

These mills have swinging hammers or bars into the path in which the coal is fed into the pulveriser. Grinding can be done by a combination of impact on the larger particles & attrition on the smaller ones. Hot air is given to dry the coals. These mills are excellent driers. It is compact low in cost and simple.

The maintenance is costly and power consumption is high, when fine powder is required. Its capacity is limited.

Pulverised Coal burners

Pulverised Coal Burners

Primary air that carries the powdered coal from the mill to the furnace is only about 20% of the total air needed for the combustion. Before the coal enters the ~~burners~~ furnace, it must be properly mixed with additional air, known as secondary air, in burners mounted in the furnace wall. In addition to the prime function of mixing, burners must also maintain stable ignition of fuel air mix and control the flame shape and travel in the furnace. Ignition depends upon the flame propagation. To prevent flash back into the ~~furnace~~ burner, the coal air mixture must move away from the burner at the rate equal to flame front travel. To ~~much~~ much secondary air can cool the mixture and prevents its heating to ignition temperature.

The important requirements of an efficient ~~good~~ powdered coal burners are

1) It should mix the fuel and primary air thoroughly and inject the mixture into the furnace.
2) It should create proper turbulence for air-fuel mixing and maintain proper combustion
3) It should be able to control the flame shape and flame travel by varying the amount of secondary air.
4) Coal air mixture should move away from the burner at the rate equal to the flame travel so as to avoid flash back.
5) It should be projected properly to avoid overheating, wear & internal firing.

Types of Burners

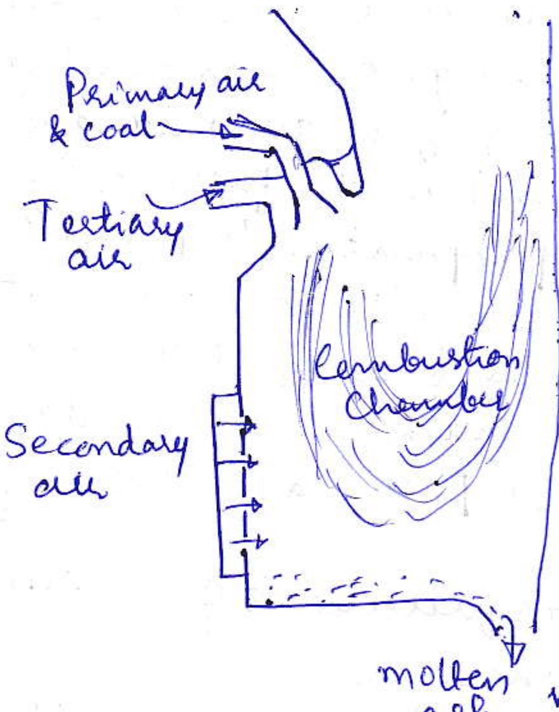
Pulverised fuel burners are classified as

1) Long flame burner.
2) Turbulent burner.

3) Tangential burners
4) Cyclone burners.

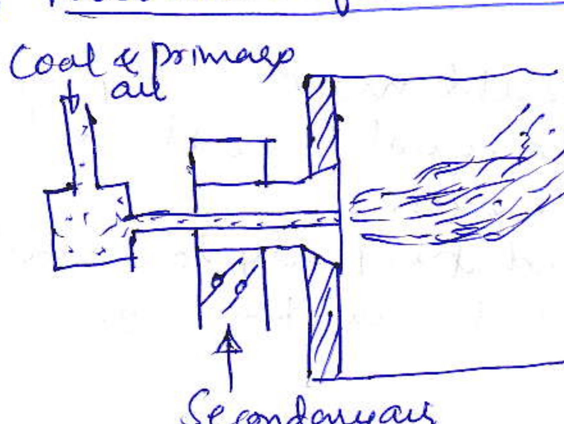
1) Long flame burners

These are also called as U-flame or Stream-lined burners.



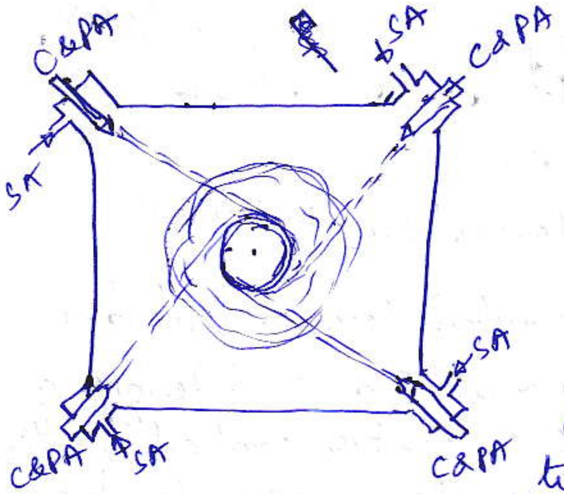
The arrangement of Primary air and coal flow and the supply of secondary air is shown in fig. Tertiary air is supplied around the burner to form an envelope around the primary air and fuel to provide better mixing. The burner discharges air and fuel mixture vertically in thin flat stream with practically no turbulence and produce long flame. Heated secondary air introduced at right angles to the flame which provides necessary mixing for better and rapid combustion.

2) Turbulent ~~flam~~ burner or Sheet flame



It is also called short flame burner. The turbulent burners are usually set into the furnace walls and project the flame horizontally in the furnace. The fuel air mixture and secondary air are arranged to pass through the burners in such a way that there is a good ~~mixture~~ mixing and the mixture is projected in highly turbulent form in the furnace. Due to high turbulence created before entering the furnace, the mixture burns intensely and combustion is completed in a short distance. This burner gives high rate of combustion compared to other types. The velocity of the burner is as high as 50 m/sec. All modern plants use this type of burners.

Tangential burners



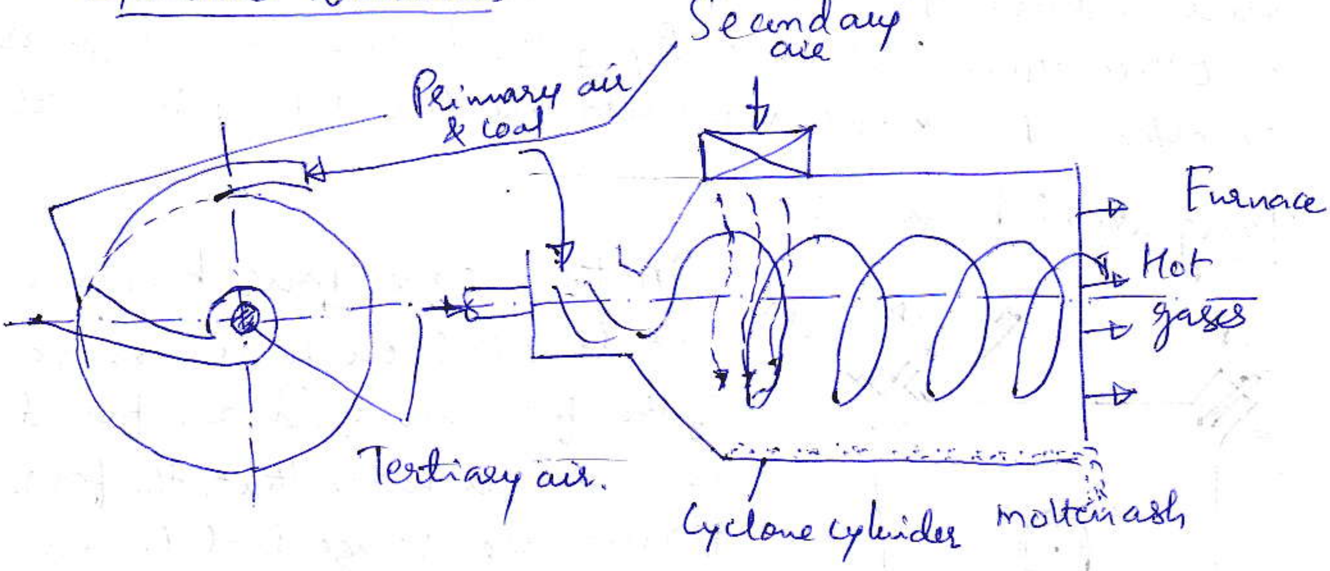
In this case, four burners are located in four corners of the furnace and are fired in such a way that, the four flames are tangential to an imaginary circles formed at the centre. The swirling action produces adequate turbulence in the furnace to complete the combustion in a short period and avoids the necessity of producing high turbulence in the burners.

This type of burners is sometimes constructed tips that can be angled through small vertical arc (±30) so as raise or lower the position of the turbulent combustion region in the furnace. This arrangement controls the temperature of the gases at the furnace aperture and maintains constant superheat temperature of the steam as load varies. When the burners are tilted downwards, the furnace gets filled completly with the flame and furnace exit gas temperature is reduced as the furnace absorption is greater. This reduces the heat given to the superheater. The reverse is true when the burners are tilted upwards. The usual limit of tilt is ±30° is sufficient to provide 100°C difference in the furnace gas exit temperature.

Advantages of tangential burners

1) The parts of the burners are well protected by furnace wall tubes
2) The operations of these burners are simple
3) The completeness of combustion is exceptionally good and maximum degree of turbulence exists throughout the furnace.
4) Liquids, gaseous and pulverised fuels can be readily burned either seperatly or in combination.

Cyclone burners



It consists of horizontal cylinderical drum having ~~varying~~ diameter of about 3m and length of about 4m. The cylinder wall is water cooled, while the inside surface is lined with chrome ore. The horizontal axis of the burner is inclined towards boilers.

The coal used in cyclone burner is crushed to about 6mm size. Coal and primary air are admitted tangential into the cylinder so as to produce a strong centrifugal motion and turbulence to the coal particles. The primary air and fuel mixture flows centrifugally along the cylinder walls towards the furnace. From the top of the ~~fur~~ burner, the secondary air is also admitted tangentially, at a high velocity of about 100 m/s. The high velocity air causes ~~the~~ further increase in centrifugal ~~force~~ motion, leading to high turbulent~~s~~ whirling motion of the coal and air mixture. Tertiary air admitted axially so as to move the turbulent coal & air mixture towards the furnace. The coal is burnt completely in the burner and only hot gases enter the furnace. Such burners produce high heat and temperatures to the tune of 2000°C. Due to high temperature burners, the ash melts in the form of slag and is drained out periodically at the bottom.

Advantages of cyclone burner

1) High furnace temperatures are obtained.
2) Simplified coal existing equipments can be used instead of costly pulverising mills.
3) The cyclone burner ~~uses~~ reduces the percentage of excess air used.
4) It can burn poorer and cheaper grade coal.
5) Boiler efficiency is increased.
6) The cost of milling ~~is~~ ~~less~~ in cyclone fire is less as the finer particals are not required
7) Fly ash problem is reduced to a greater extent.

Disadvantages

1) High cost.
2) It requires high pressure draught and consumes higher power.
3) It produces more oxides of nitrogen, which creates atmospheric pollutions.

Fuel oil burning systems

The functions of an oil burner are to mix the fuel and air in proper proportion and prepare the fuel for combustion.

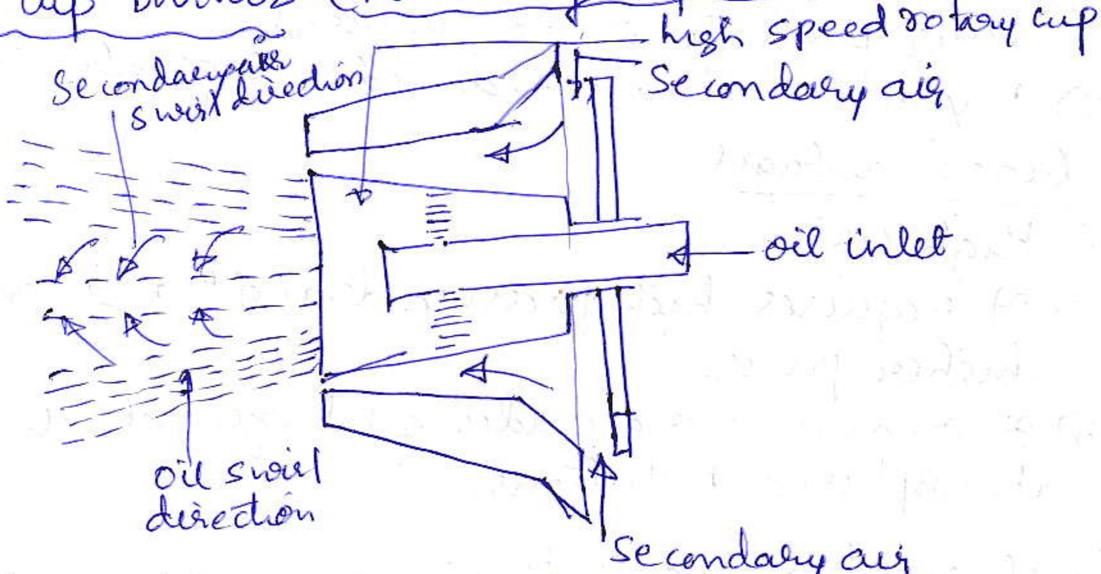
Classification of oil burners

1) Vapourising oil burners
   - (a) Atmospheric pressure atomizing burner.
   - (b) Recirculation burner.
   - (c) Wick type burner.
2) Atomising burner.
   - (a) Rotary cup type
   - (b) Mechanical or oil pressure burner.
   - (c) Steam or high pressure air burner

Requirements of Vaporising or atomising burners

1) To vaporise the fuel before ignition
2) To mix the vaporised fuel thoroughly with air
3) To minimise soot formation
4) To ~~release~~ give high heat energy by burning large quantity of ~~oil~~ oil per hour.
5) To allow for efficient combustion of fuel at part load conditions.

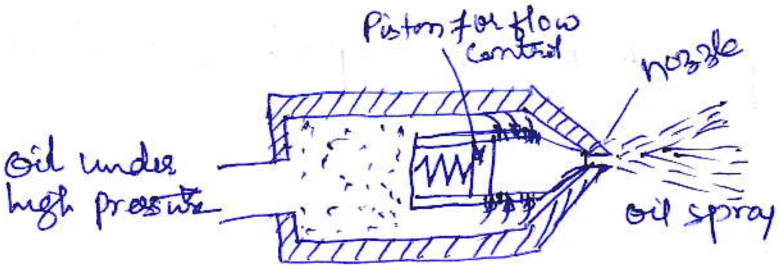
Rotary Cup burner (Rotating cup burner)



It consists of a horizontal rotary cup that runs at a high speed of about 3000 rpm. The oil supplied at the centre through the inlet port and sprayed on to inner surface of the rim of the high speed rotary cup. The oil is spun off the high speed cup due to centrifugal force as very ~~high~~ fine particles into the air stream entering the cup periphery, thus atomising the oil. The direction of rotation of cup and the direction of flow of air are opposite such that both mix thoroughly by swirling action as they leave the burner and burn easily. Such burners have a wide capacity ranges, as the rate of oil burnt can be easily regulated by controlling the inlet port size at the centre of the cup.

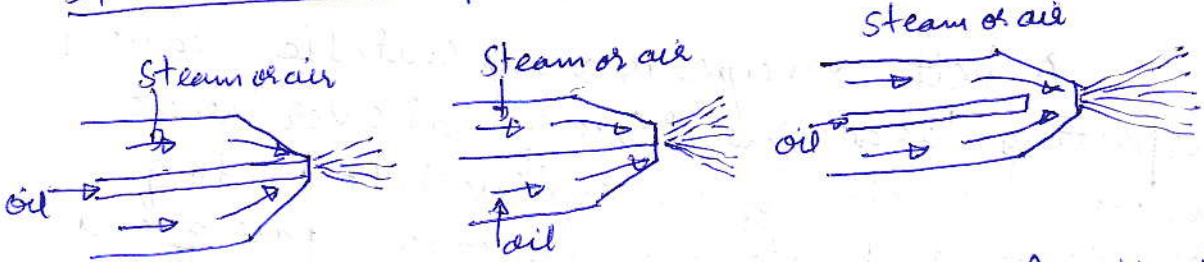
2) Mechanical or oil Pressure burner

In these burners the oil is subjected to high pressure and atomised by passing through the orifice



The oil is supplied under high pressure of 10 to 20 bar. Usually the oil passes through the swirl chamber and thoroughly get mixed with primary air. As the oil under pressure is ejected out of the orifice, it breaks down into fine particles forms a conical oil mist and easily undergoes combustion. The oil flow through the orifice can be regulated with the help of control piston (plunger) which closes the tangential slots to the required level.

Steam or high pressure air burner



In these burners the oil is atomised with the help of high pressure air or steam. The high pressure air or steam enters the nozzle and mixes with the fuel. The air and oil are supplied through different channels and are mixed either within the nozzle before leaving it or outside the nozzle after leaving it.

Wick burners

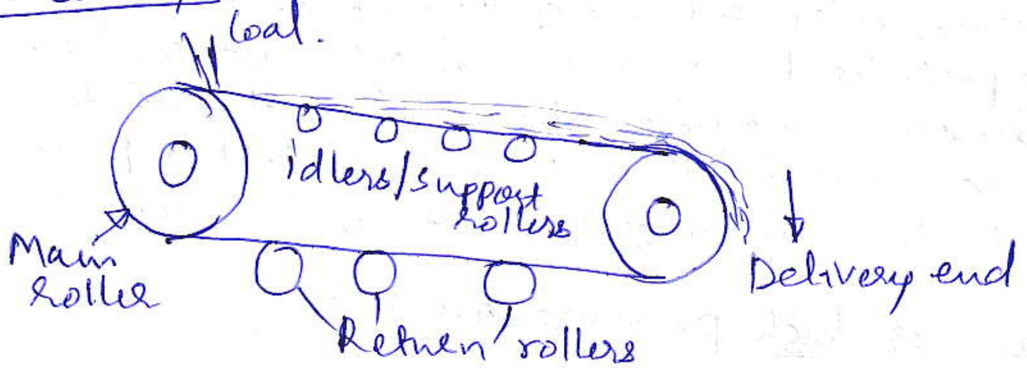
In this type of a burner a cotton or asbestos wick is used which raises the liquid fuel by capillary action. The fuel from the uppermost part of the wick is evaporated due to radiant heat from the flame and nearby heated surfaces. Air is admitted through the holes in the surrounding walls.

Coal handling

The process of conveying the coal from the point of unloading to the place of use is referred as coal handling.

The important equipments for transporting coal in a power plant are
1) Belt conveyors
2) Screw conveyors
3) Bucket elevators
4) Grab bucket elevators.

1) Belt conveyor



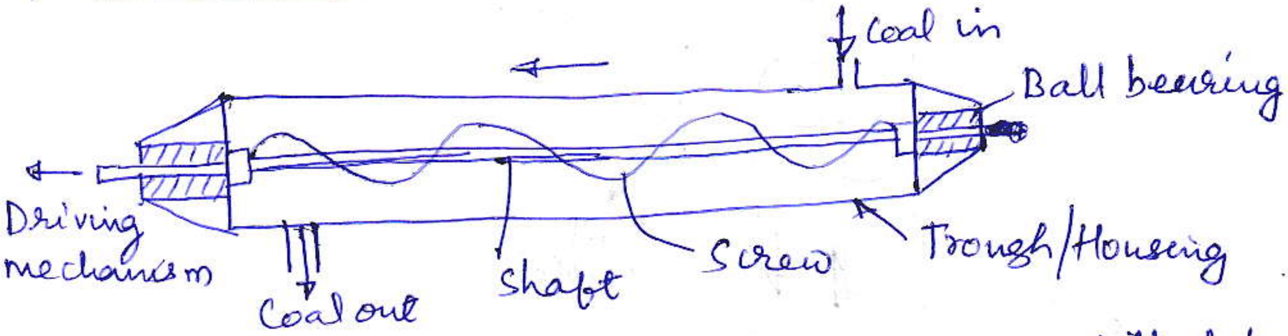
A belt conveyor is very suitable means of transporting large quantities of coal over large distances. It consists of an endless belt made of rubber, canvas or balata running over a pair of end rollers and supported by series of rollers known as idlers provided at regular interval. The return rollers ~~noted~~ which support the empty belt are plain rollers and spaced wide apart. The belt is inclined at about 15-20° degrees from the charge end to the discharge end. The average ~~belt~~ speed of the belt conveyors is in the range of 100m/min.

Advantages
1) Its operation is smooth & clean
2) Repair and maintenance cost are minimum.
3) Large quantity of coal can be discharged quickly & continuously.
4) Power consumption is minimum.
5) The rate of coal transfer can be easily varied by just varying the belt speed.
6) It is simple in construction & operation

Disadvantages
1) Not suitable for greater height & lesser distances

2) As the maximum inclination at which coal can be transfered by this arrangement is minimum

2) Screw Conveyor



It consists of endless helical screw fitted to a shaft. The driving mechanism is connected to one end of the shaft and other end of the shaft is supported in an enclosed ball bearing. The screw while rotating in a trough/housing transfers coal from one end to the other end. The following particulars are related to this screw conveyor.

Diameter of the screw – 15 to 50 cm
Speed – 70 to 120 rpm
Maximum capacity – 125 tons/hour.

Advantages

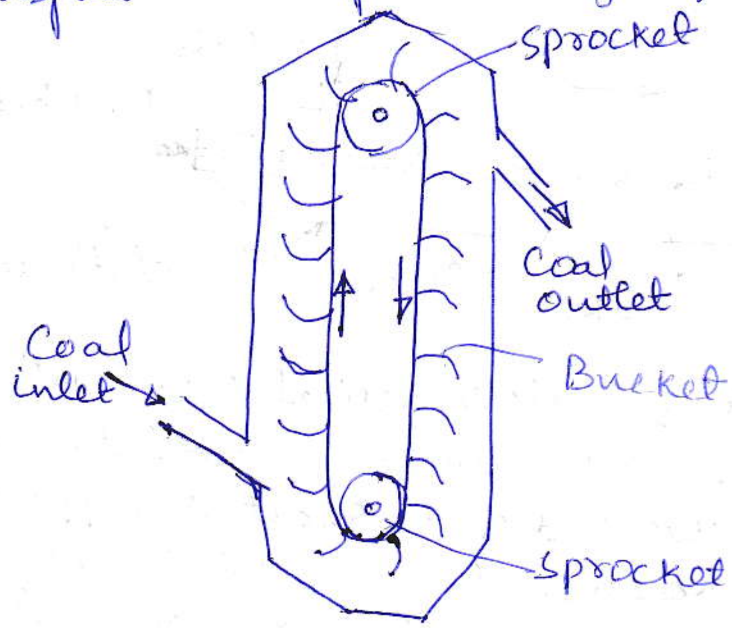
1) It is relatively inexpensive
2) It requires minimum space for operation
3) It is very simple and compact.
4) It can be made dust-tight

Disadvantages

1) Power consumption is comparatively high
2) It is suitable for only short distance transportation say 20 to 30 m
3) Wear & tear of the parts is more.

Bucket elevator

This type of conveyor is used for moving the coal vertically up. It consists of number of buckets fixed on a chain moving over two sprockets. The coal is picked up by upmoving buckets from the bottom part of the conveyor. The coal from the buckets is discharged at the top due to centrifugal force of the buckets change the direction. Usually such conveyors can transport coal upto a height of 30 m.



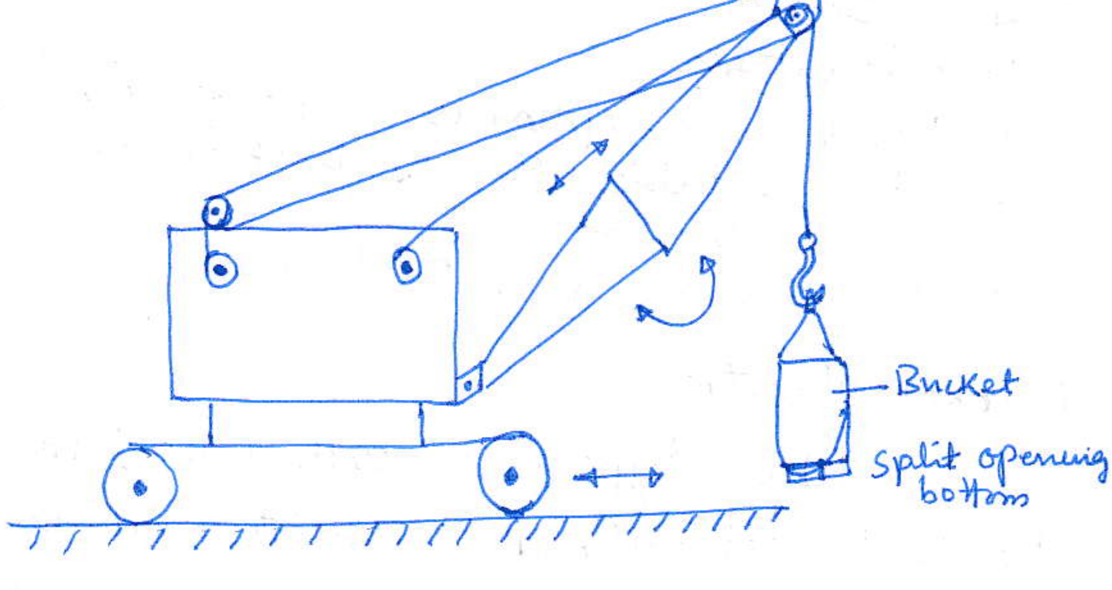
Advantages

1) Less power is required for operating the equipment
2) Coal can be discharged at elevated places
3) Less floor area is required.

Disadvantages

1) The capacity is limited and hence not suitable for large capacity stations.

4) Grab bucket Conveyor



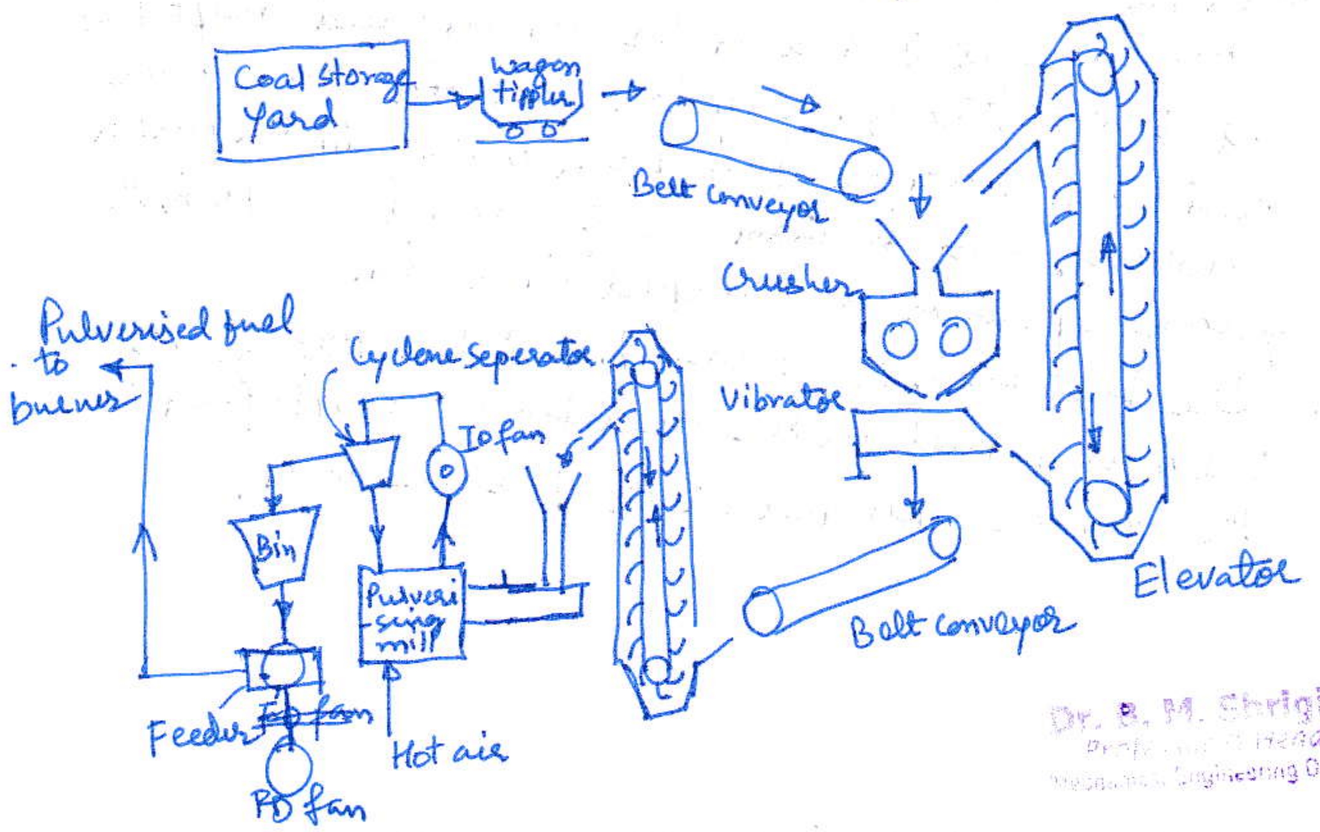
It consists of a crane which can lift the coal and move circumferencially in a given location. It transfers the load on a single rail or track from one point to another. This is costly machine and ~~yes~~ is justified only when other arrangements are not possible.

This elevator has a unique advantange of operat-ing as a crane as well as moving in all directions, move to the required direction and unload it onto the wagon tippler. The grab bucket ~~at the~~ with bottom closed condition picks up the coal from the heap and when moved to the wagon opens its split opening bottom, thereby dumping the coal into the wagon.

Flow of coal in power plants

The sequence of flow of coal in the power plant is as follows

1) Storage yard to wagon using grab bucket elevator
2) Wagon to belt conveyor
3) Belt conveyor to crushers/Seperator
4) Seperator to belt conveyor to bucket elevator
5) Bucket elevator to pulveriser
6) Pulveriser to bin and to furnace



1) The raw coal from the storage yard is lifted and loaded to the wagon tippler using grab bucket elevator. Grab bucket elevator is convinient to load coal as it operates like a crane and moves as well in all directions.

2) The wagon tippler moves on the rail from the storage yard to the ~~bucket elevator~~ belt conveyor and the coal is unloaded by tilting the wagon tippler by a tilting mechanism.

3) The belt conveyor carries the raw coal to a crusher where the coal is crushed to smaller size and passes to a vibrator seperator. Oversized particles from the seperator are lifted and transported back to the crusher using a bucket elevator for further crushing.

4) The required sized coal then moves on another belt conveyor and lifted by another bucket elevator to the hopper of the pulverising mill

5) The coal is then powdered in a pulverising mill, where hot air is passed to remove moisture from the coal and for easy powdering action. The powdered coal is drawn by an induced draft fan and passes through a cyclone seperator where over-sized coal particles fall back to the mill for further crushing. ~~and is then~~ The powdered coal from the cyclone seperator is dumped in a bin.

6) The fuel from the storage bin is fed through the pulverised fuel feeder by a forced draft fan to the burner mounted in the furnace walls.

Ash Handling

Coal based steam power plants produce a large quantity of ash. The amount of ash produced is about 20 to 30% of the coal burnt. Ash handling in power plant is a major problem since ash taken out from the furnace is hot, dusty, ~~ais~~ messy to handle and comes out with some gases that are hazardous to the heath of workers. Generally before handling the ash from the furnace is first quenched in water for the following reasons.

1) Water quenching reduces the temperature of the ash, hence can be handled easily.
2) It dilutes the ash, thus reducing its corrosive nature
3) Large lumps of ash clinkers get disintegrated after quenching, thus makes it easier to handle.
4) On quenching, the dust particles and some hazardous gases in ash get dissolved in water and reduce the pollution problems

Requirements of ash handling

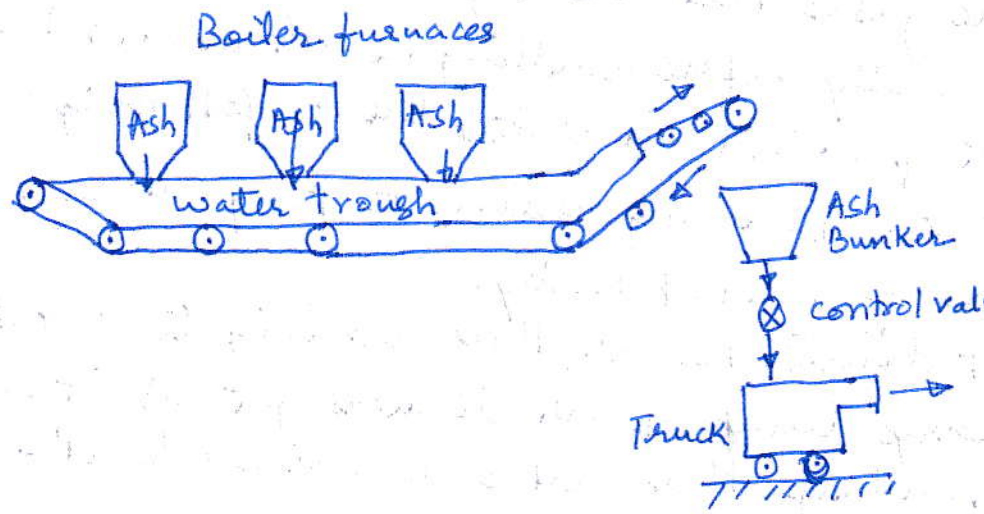
1) Capital costs, operating and maintenance ~~cos~~ charges should be low.
2) It should be able to handle large quantities of ash.
3) It should be able to handle hot and wet ash effectively and with good speed.
4) It should be possible to minimise the corrosive or abrasive action of ashes
5) The operation of the plant should be noiseless
6) In case of additions of units, it should ~~be~~ need minimum changes in original layout of plant.
7) The plant should have high rating.

Ash handling systems

The modern ash handling system is mainly classified into four groups

1) Mechanical handling system
2) Hydraulic handling systems
3) Pneumatic handling system
4) Steam jet handling system.

1) Mechanical Ash handling systems



Mechanical ash handling systems are suitable for small and medium capacity power plants.

It is a conveyor based ash handling system. The hot ash from the furnaces is dumped to a water trough, where it is quenched. The quenched ash is then discharged over a belt conveyor. The cooled ash is then conveyed by the belt to a distant dumping site, from where it is collected in a bunkers and transported by means of trucks for further disposal.

The life of mechanical ash handling system is about 5 to 10 years. The average ash handling capacity of such a system is 5 tons/hour.

Advantages

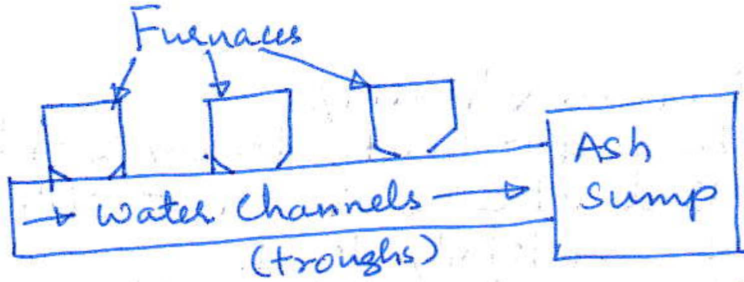
1) ~~Simple~~ Simple in construction
2) Easy to operate
3) ~~Easy~~ low power consumption
4) Continuous ash handling

2) Hydraulic Ash Handling system

In this system, ash is carried with the flow of water with high velocity through a channel and finally dumped in a sump. This system is subdivided into two types

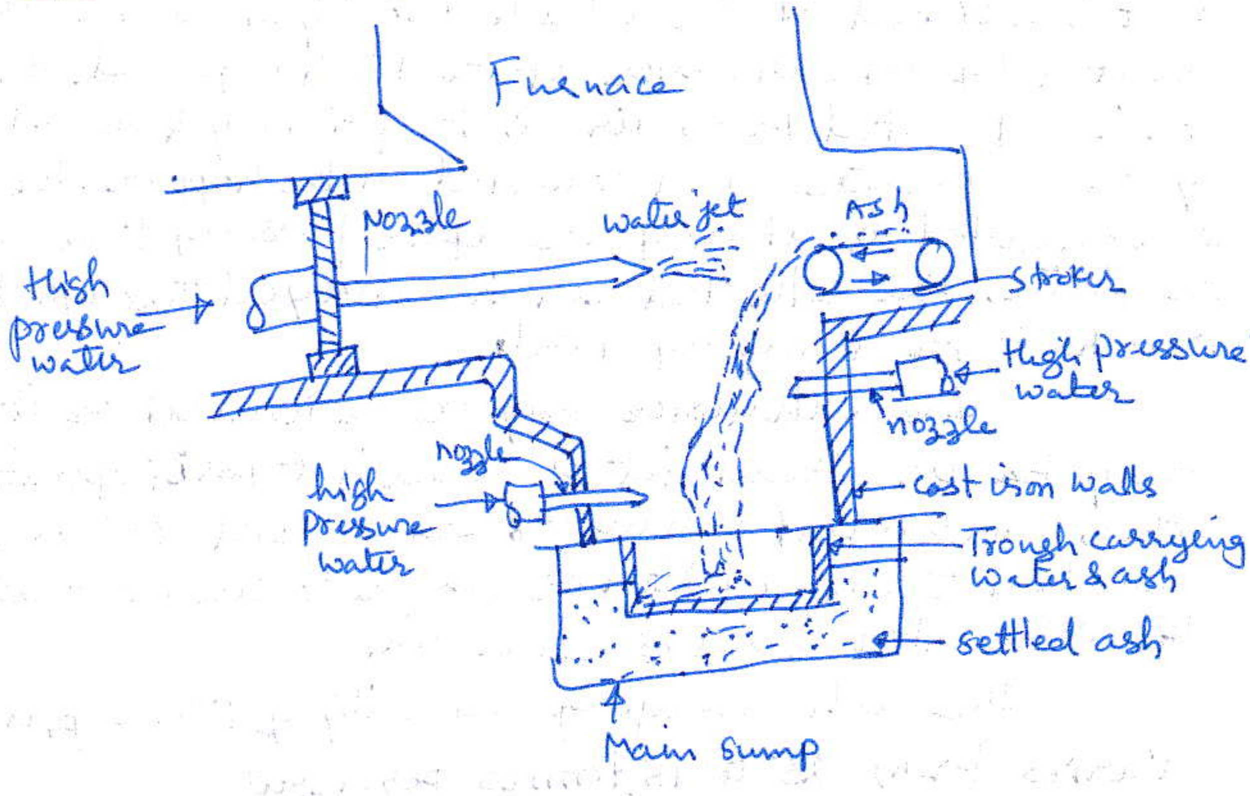
1) Low velocity system (Low pressure System)
2) High Velocity Systems (High pressure system).

1) Low velocity system (Low Pressure System)



In this system, the ash from the furnaces is discharged into a flowing water channel. The water flows at a low velocity of about 3-5 m/s and carries the ash along with it. At the sump ash is seperated from the water and water is reused. This system has a ash carrying capacity of 50 tons/hour and carry ashes upto 1 km.

2) High velocity system (High pressure system



In this system, the hot ash from the furnace is quenched by a set of water jets. Another set of nozzles at the lower portion of the system, give out high velocity of water jets, which gives driving force to carry ash to the sump. The cooled ash with high velocity water is discharged to the sump, where water and ash are seperated. The ash handling capacity of such systems is 100tons/hr and can carry ash upto 2Km. Troughs and sumps are constructed using corrosion resistant material, since the ash is highly corrosive.

Advantages

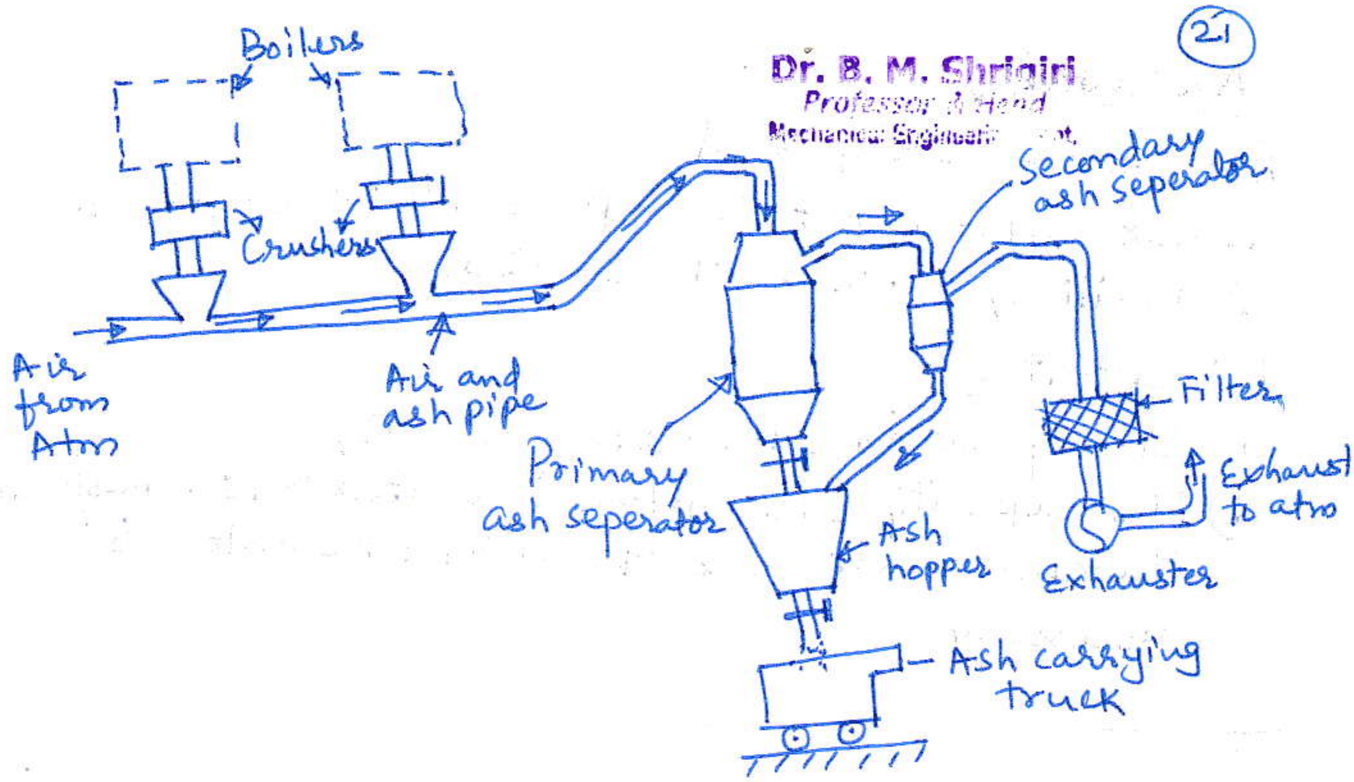
1) The system is clean & healthy.
2) It can also be used to handle stream of molten ash.
3) Working parts donot come in contact with the ash.
4) It is dustless and totally closed.
5) It can discharge ash to higher distances 2 Km at faster rates
6) The ash carrying capacity is considerably large, hence suitable for large thermal power plants.

3) Pneumatic Ash Handling system

In this system, ash from the furnace is crushed in crushers to small size, so that it can be handled easily by pneumatic means. The powdered ash and dust are picked up by a high velocity stream of air created by an exhauster at the discharge end. The ~~air~~ ash is seperated from air in the primary & secondary cyclone seperators and collected in the hopper. The air is exhausted to atmosphere after passing through the filter. The collected ash is conveyed through the trucks to the dumping yards.

The exhauster may be mechanical or it may ~~be~~ use steam jet or water jet for its operations. When mechanical exhausters ~~are~~ is used, it is usually essential to use a filter or washer to ensure that the exhauster handles clean air.

The ash carrying capacity of this systems varies from 25 to 15 tonnes per hour.



Advantages

1) No spillage & rehandling
2) High flexibility
3) There is no chance of ash freezing or sticking in the storage bin and material can be discharged freely by gravity.
4) The dustless operation is possible as the materials are handled totally in an enclosed conduit.
5) The cost of the plant per tonne of ash disposed is less in Comparision with other systems.

Disadvantages

1) There is a large amount of wear in the pipe work necessiating high maintenance charges.
2) More noisy than other systems.

4) Steam jet system

In this system, steam under high pressure carries the ashes through the pipe line under high velocity. The jet of high pressure steam is passed in the direction of ash travel through the conveying pipe. The ash is deposited in the ash hopper.

Advantages

1) Less space required
2) Less capital cost in comparison to other systems.
3) Auxiliary drive is not required.

Disadvantages

1) The operation of the system is noisy
2) The capacity of the system is limited to 15 tonnes/hour therefore continuous operation of the system is necessary

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Analysis of coal

The classification of coal is based upon the physical and chemical composition of the coal and it is therefore necessary to study about the chemical composition of the coal.

The common tests which are used to find the commercial value of coal are proximate analysis and ultimate analysis of the coal.

Proximate Analysis:- The proximate analysis of coal gives the composition of coal in respect of moisture, volatile matter, ash and carbon. The proximate analysis of most coals indicates the following ranges of various constituents

Constituents	Moisture	Volatile Matter	ash	Carbon
Percentage	3 to 30%	3 to 50%	2 to 30%	16 to 92%

The constituents given by the proximate analysis mostly decide the adoption of coal and design of power plant. The role played by each constituent in adopting coal for power plant is discussed below.

1) **Moisture**:- All coal contains some percentages of moisture and it generally varies from 1-40%. The moisture in the coal exists in two forms as inherent and free moisture. The inherent moisture is the combined moisture and that is held in the pores of coal. The percentage of inherent moisture is determined by heating the coal to 110°C in the current of nitrogen. The inherent moisture is never removed from the coal used for power plants as it is a costly process.

The free moisture is defined as the moisture present in the coal, which can be removed just by exposing the coal to the natural air flow or by drying with the help of air at 50°C

Here we are mostly interested in free moisture in the coal as it has important effects on the plant. The presence of moisture in the coal is objectionable as it adds to the transporting, handling and storing of cost of ~~of~~ coal and doesnot play any useful role. Moreover, it decreases the heating value of the fuel and part of heat generated is also carried away as it goes as vapour with exhaust gases. The another added disadva-ntage of moisture is, it quenches the fire in the furnace of the boiler. Therefore, the coal which is used in power plants is generally dried and the free moisture is removed from the coal.

2) Volatile matter :- The volatile matter present in the coal may be as high as 50%. The volatile matter present in the coal may be combustibe gases such as methane, hydrogen, carbon monoxide and other hydrocarbons or incombustible gases like CO_2 & N_2. The presence of incombustible gases is always undesirable as they donot add in heat value, but increases the volume of furnace required. ~~The~~ Overall, ~~the coal which is used in power plants is generally dried~~ the volatile matters affects the furnace volume, and arrangement of heating surfaces.

3) Ash :- Ash is another most undesirable constituent of coal. The ash content in the coal present in two forms as fixed ash and free ash. The fixed ash present in the coal comes from original vegetable matter and it can not be removed from coal before burning the coal.

The free ash comes with the coal in the form of clay, shale & pyrites. The free ash can be reduced or removed by mechanical processing of coal such as washing & screening, but the presence of fixed ash is more or less unavoidable.

The presence of ash like ~~coal and~~ moisture also increases transporting, handling and storage costs. It also decreases the heating value of the fuel and involves additional cost in ash disposal. The presence of ash with coal ~~also~~ also causes early ware of furnace walls, burning apparatus and feeding mechanism.

Another disadvantage of ~~coal~~ ash is the formation of clinker. The clinker formation on the grate of the furnace may choke air passages and remain attached with the unburned fuel. This also causes the loss of fuel. The percentage of fixed ash in coal mostly decides the type of the combustion chamber, burners and feeding system used in power plants. It is always economical to use high ash content coal in the form of powdered coal as it eliminates the clinkering difficulties and reduces the loss of fuel and helps for efficient burning.

Ultimate Analysis :- The proximate analysis of coal doesnot give any idea about suitability of coal for the purpose of heating. It is also not possible to find out the calorific value of coal with the help of proximate analysis.

To find out the chemical ~~comp~~ analysis of coal like carbon, hydrogen, oxygen, nitrogen, sulphur and ash, Ultimate analysis of coal is ~~used~~ generally used.

The chemical analysis of coal alone is not ~~used~~ enough to find out the suitability of coal for heating purposes, however, ~~i~~ it is very useful to find out the composition of flue gases.

The ultimate analysis of most coals indicates the following ranges of various constituents

Constituents	Carbon	Hydrogen	oxygen	Sulphur	Nitrogen	Ash
percentage	50-95%	1-5.5%	2-40%	0.5-3%	0.5-7%	2-30%

The role ~~adopted~~ played by each constituent calculated by Ultimate analysis in adopting coal for power plant is discussed as under.

1) Carbon :- The percentage of carbon plays most important role in the selection of coal for thermal power plant. Higher percentage of carbon gives high heat value and reduces the size the combustion chamber required.

2) Hydrogen :- It is always assumed that part of hydrogen exists in the coal in combined form with oxygen known as inherent moisture. The inherent moisture is objectionable as it carries heat with flue gases without playing any part in combustion. High percentage of hydrogen is always desirable as it increases the heating value of the coal.

3) Nitrogen :- The percentage of nitrogen in coal does not play any importance in the combustion calculations as it has no heating value.

4) Oxygen :- The oxygen which is present in coal is always in combined form with hydrogen. Low percentage of oxygen is always desirable as it reduces the percentage of hydrogen available for free heating.

5) Sulphur :- The percentage of sulphur in coal varies from 0.5 to 7 %. It adds little heating value, but furnishes many undesirable characteristics. The high percentage of sulphur is highly objectionable because the sulphur is responsible for clinkering, slagging, corrosion of air preheaters, economizers and stacks, spontaneous combustion during storage, and air pollution

6) Ash :- Ash is residue from combustion, while clinker is caused by melting this ash. The ash contains silica, alumina, ferric oxide, calcium oxide, magnesium oxide, and alkalies. It also contains 1 to 2 % sulphur.