B. E.

Eighth Semester Examination, Dec-2008

POWER PLANT ENGINEERING

Note : Attempt any five questions. All questions carry equal marks.

Q. 1. (a) Compare hydro and thermal power plants.

Ans. The steam power plants use solid fuel or coal in the pulverised form in burners or furnace oil in oil burners. Pulverized fuel firing is most common in large stations. Steam is produced in the boiler and is expanded in steam turbines which are coupled to electric generators, generating electricity. The plant may contain several heat reclaiming devices such as economisers, air preheaters, feed water heaters etc.

In hydro electric power stations water is stored behind a dam at an elevation. The potential energy of water is converted to mechanical energy allowing the water to flow through water turbines. Generators are couple to water turbines hence electric power.

Q. 1. (b) At a particular site the mean monthly discharge is as follows :

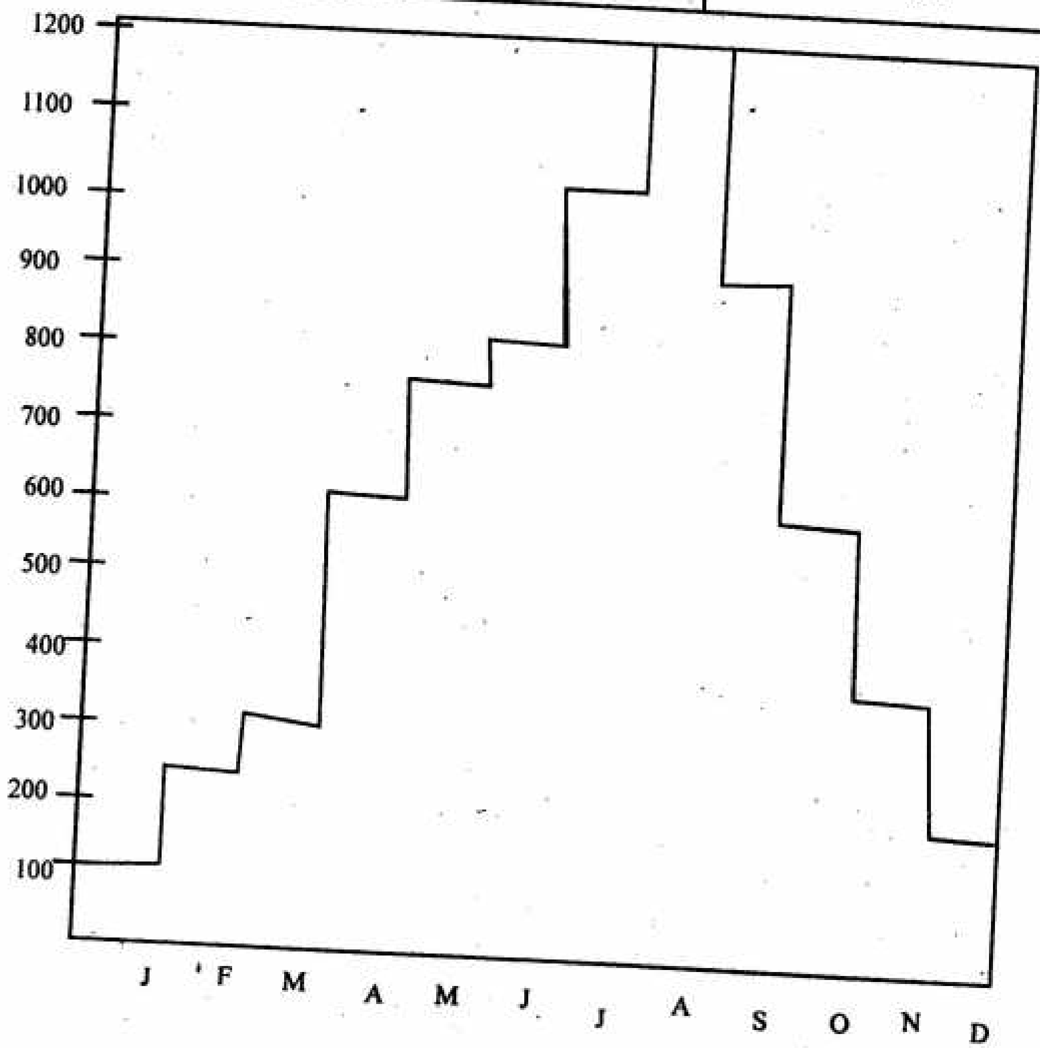
Month	Jan	Feb	Mar	Ap	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Discharge m^3/s	100	225	300	600	750	800	1000	1200	900	600	400	200

Draw hydrograph and flow duration curve.

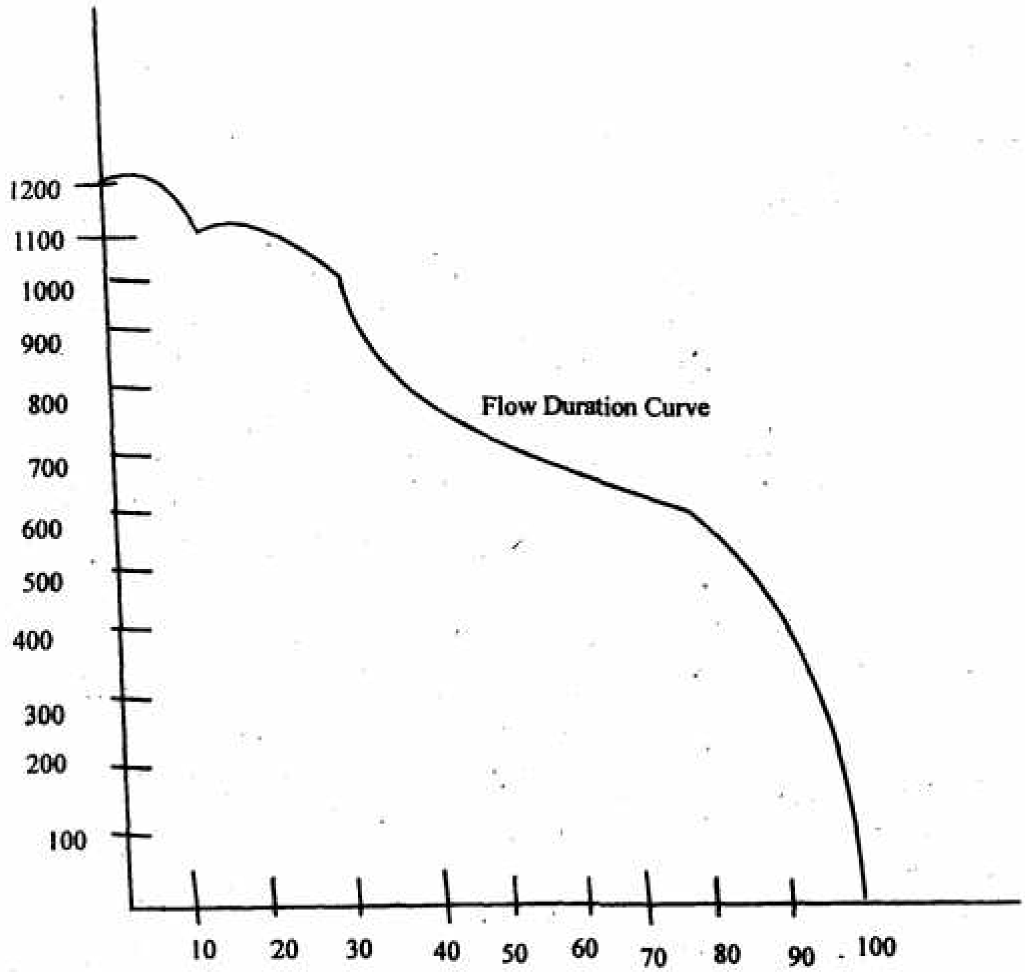
Ans.

Discharge	Total number of month	Percentage time
$100\,m^3/s$ (or more)	12	100
$200\,m^3/s$ (or more)	11	91.66
$300\,m^3/s$ (or more)	9	75
$400\,m^3/s$ (or more)	8	66.66
$500\,m^3/s$ (or more)	7	58.55
$600\,m^3/s$ (or more)	7	58.55
$700\,m^3/s$ (or more)	5	41.66

$800 m^3/s$ (or more)	4	33.33
$900 m^3/s$ (or more)	3	25
$1000 m^3/s$ (or more)	2	16.66
$1100 m^3/s$ (or more)	2	16.66
$1200 m^3/s$ (or more)	1	8.33



Hydrograph



Q. 2. Discuss the following in case of steam power plant :

(a) Preparation of coal

(b) Belt conveyor

(c) Electrostatic precipitator

(d) Comparison of unit and central system of pulverised fuel firing system.

Ans. Preparation :

The preparation of coal before feeding to the combustion chamber include sizing of the coal (if brought unsized), drying and removing the iron particles.

A coal preparation plant includes the following equipments :

(a) Crushers,

(b) Breakers,

(c) Sizers,

(d) Dryers and

(e) Magnetic separators

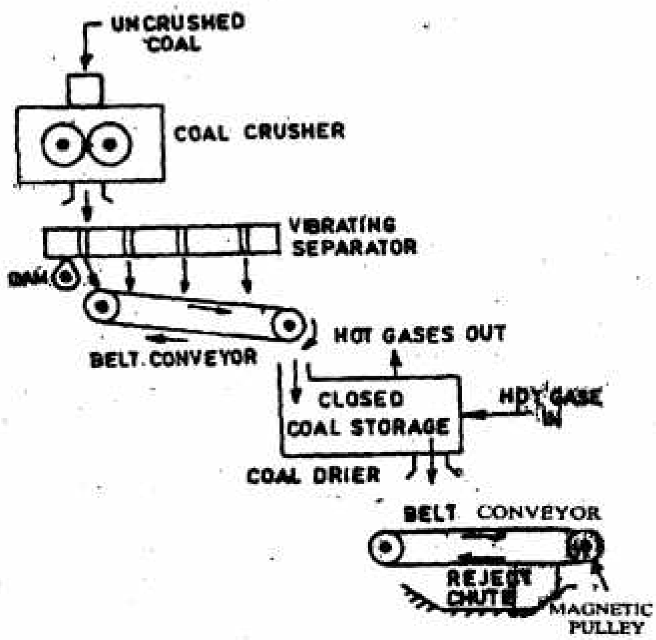


Fig. Schematic diagram of a coal preparation plant

Fig. shows a coal preparation plant. Many types of coal crushers are in the use for reducing the coal to required size. Part of the coal obtained from coal fields does not require sizing, crushing plant may be by-passed. The capacity of the crushers in large central stations as high as 600 tons per hour. Sizers are used along with crushers and breakers. The coal driers are used in order to remove the excess free moisture from cola or if it is wetted during transport. Hot flue gases are passed through the coal storage.

The iron particles which may be brought with coal from the coal fields, are removed with the help of magnetic separators. These iron particles may choke the burners and may increase the wear of handling equipment. The iron particles cling to the belt, where the coal falls off sooner, and dropped into a reject chute. The iron particles may be coal cutter teeth particles, bolts, nuts, wire fish plates etc. A small amount of bolts and nuts may enter the coal from the feeders, conveyors and elevators, and it is therefore desirable that the separator be placed as close as possible to the coal preparation plant, and in any case before passing on the storage bunkers. Magnetic separation is more desirable with pulverised fuel than stoker fired plant. The latter will pass trapped iron without any risk of damage, but the feeders and milling plant associated with the former may be damaged.

(b) Belt conveyor :

This device is used for holistic conveying. It is successfully used on inclinations upto horizontal. The average speed ranges from 60 to 100 m/a load carrying capacity of about 50 to 100 tonnes per hour easily be transferred through 400 metres. Thus these can be used in large stations. In its simplest form the belt conveyor consists of a belt of a suitable material as rubber, canvas etc., running over a pair of end drums of pulleys and supported at intervals by a series of rollers called idlers these in turn being supported on a conveyor frame. The carrying idlers, which support the located side of the belt are usually toughened to provide a sag in the belt section. These prevents loose materials from falling down the belt at the sides.

The advantages and disadvantages of belt conveyor is listed below :

Advantages :

(i) Continuous discharge of coal is achieved.

(ii) Operation is smooth and clean.

(iii) The coal over the belt can be easily protected from wind and rain by providing over head covers.

(iv) Power consumption is less as compared with other types of transport systems.

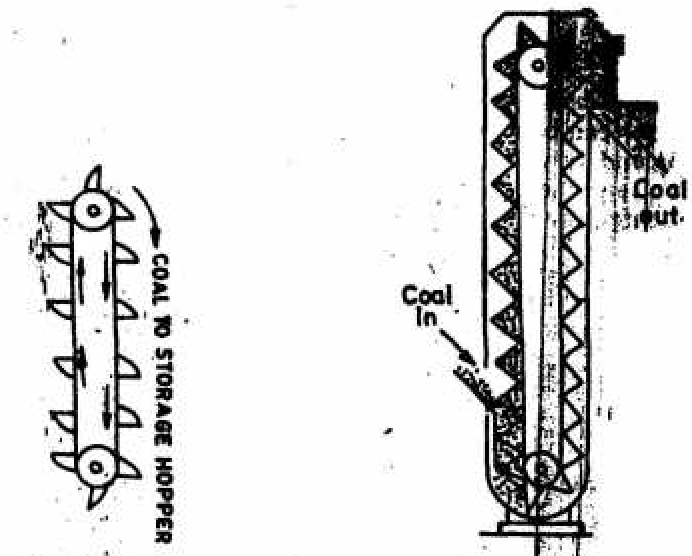
(v) Large quantity of coal can be transferred.

(vi) The repair and maintenance costs are minimum.

Disadvantages :

(i) It is not suitable for short distances and greater heights.

(ii) As the maximum inclination at which coal can be transported is limited (20°), moreover length of the conveyor becomes excessive if coal is transferred at considerable height.



(a) Bucket elevator (Centrifugal).

(b) Bucket conveyor (Continuous type).

Fig. 5·2·4.

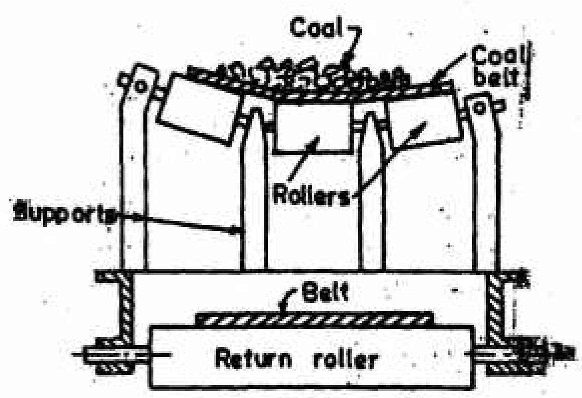
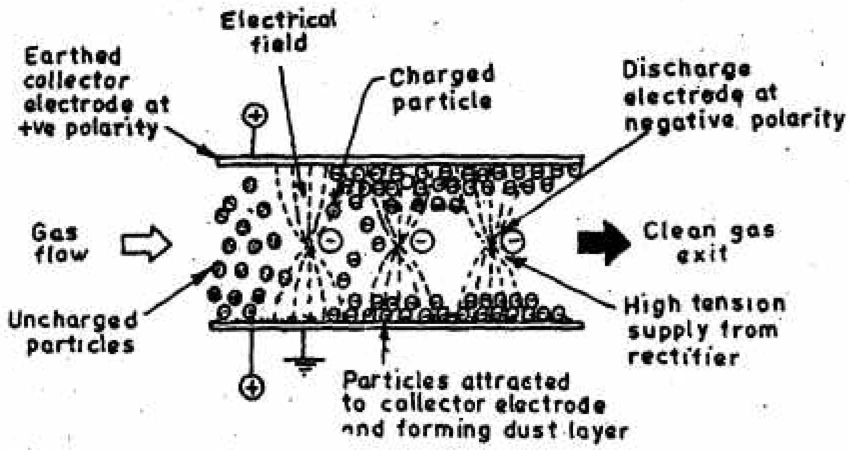


Fig. Section through belt conveyor

(c) Electrostatic precipitator (ESP) :

Introduction :

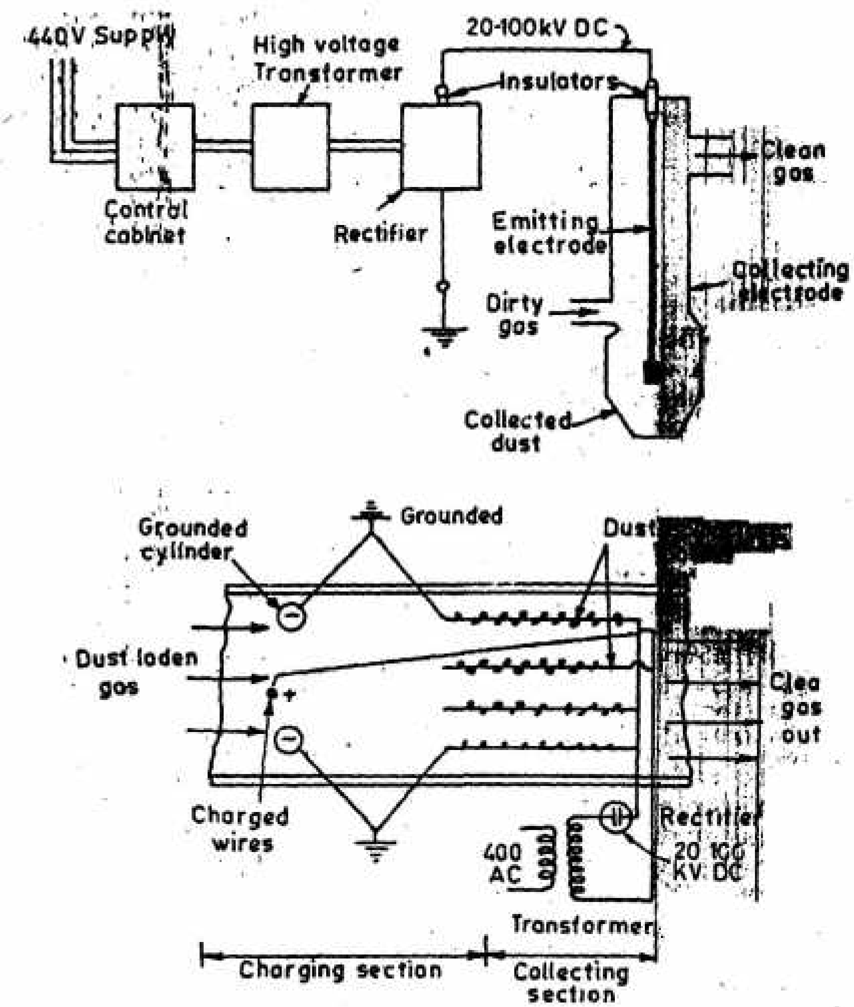


Basic principle of electrical precinitator

This type (also called cottrell precipitators) work efficiency on the finer flue dust. In this precipitator, and electric charge or electrostatic field at high voltage is imposed on the dust. The precipitator Fig. (a) (b) and (c), has two sets of electrodes which are insulated from each other and between which the 'flue gases' are made to pass. The dust particles are ionized as the gas passes through the electric field, are attracted by the collecting electrode which is grounded. The other electrode is maintained at a negative potential 20,000 to 100,000 volts. The collecting electrodes have a large contact surface. Accumulated dust fall off the electrode when it is raped mechanically (or shaking motion is given). Hence principal parts are :

1. Source of high voltage,
2. Ionizing and collecting electrodes.
3. Dust removal mechanics, and
4. Shell to house the elements.

The collecting electrode is made in such shapes as would give a large surface for the material to deposit while the other electrode has shape having curved edges which creates a strong static field.



Arrangement in an electrostatic precipitator

(d) Central system :

- The raw coal from the overhead bunkers is delivered to each mill through an automatic weigher if desired. From the pulverizer (Fig.,), mill the pulverized coal passes through a classifier or separator which rejects and returns to the mill any oversize particles. The coal is dried in the mill by either hot air or flue gas which is forced through it and carries the powdered coal to the cyclone. The coal-laden air then passes from the separator to a cyclone where the air is separated from the coal powder, and being returned to the mill circuit by an exhauster fan. From the cyclone, the pulverised coal is delivered to a bin (or bunker) via a screw conveyor. This bin may contain 12 to 24 hours' supply of pulverized coal. From the bin the coal is metered to the burners by motor driven feeders of varied design, primary air, added at the feeders, floats the coal to the burners.

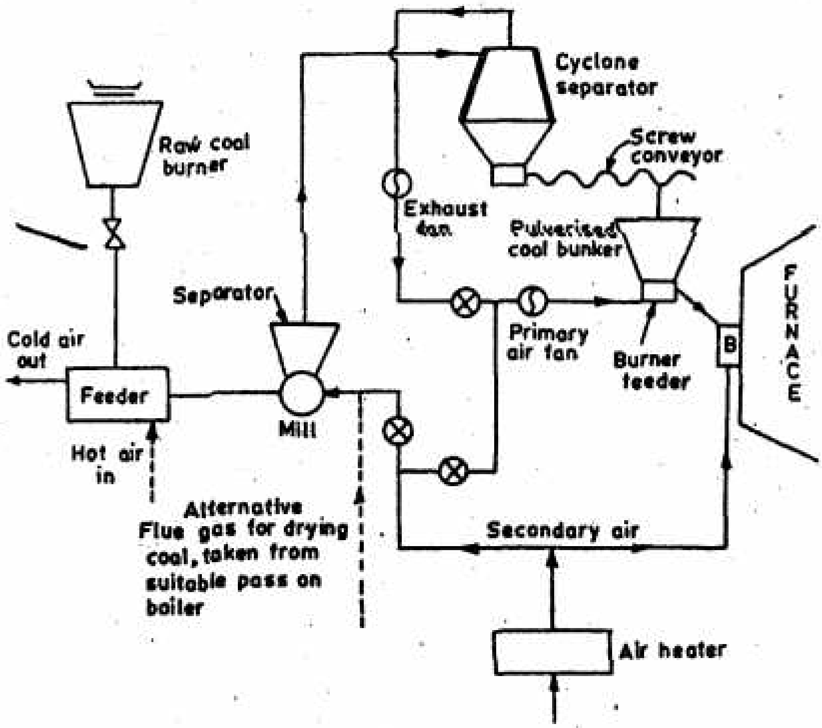


Fig. Pulverized fuel central system

Advantages of Central or Bin system :

1. Boiler plant is more reliable since failure of coal preparation plant does not immediately affect operation, because the plant has got always some fuel in reserve.
2. There is large degree of flexibility, as fuel and air quantities can be accurately controlled enabling the boiler outputs to be varied over wide range.
3. The coal preparation plant can be shut down during peak load, as there are storage bunkers when sufficient reserve capacity has been achieved.
4. Burners can be operated irrespective of the coal preparation plant.

5. Exhauster fans handle only air, so minimum wear takes place, compared to unit system, where air and coal both are handled by the fan.
6. The coal preparation plant can be worked continuously of its designed rating and, therefore, maximum efficiency. The fuel is prepared on a mass production basis with consequent savings.
7. The coal may be pulverized at constant rate independent of load and during off peak hours.
8. The mills can be pulverise at the most economical rate and at a constant degree of fineness.
9. Wear on the mill does not affect fineness of coal or the capacity of the boiler.
10. Less labour is required.
11. The boiler room may be kept clean.

Disadvantages :

1. Higher capital cost.
2. Larger building space is required.
3. Central preparation plant may require a separate buildings.
4. There is possibility of fire and explosion hazards.
5. More plant operators are required, thus increasing operation charges.
6. Driers are usually necessary.
7. Fire hazard of quantities of stored pulverized coal.
8. Maintenance charges are higher.
9. The auxiliary power consumption is higher.
10. The greater number of auxiliary unit, i.e., cyclones, conveyers, storage bins primary air fans etc.

Unit system :

Most pulverized coal plants are now being installed with unit pulverizers. The unit system is so-called from the fact that each burner or burner group and the pulverizer constitute a unit, i.e., one set of feeder mill fan is used exclusively for one burner. Thus, a boiler using more than one burner will have a number of such circuits equal to the number of burners.

The Unit Direct system refer fig., consists of a feeder, pulverizer, separator, fan, coal and air pipes and burners. The pulverizer, together with feeder, separator and fan, may be arranged to form a complete unit or mill, the number of unit required depending upon the capacity of the boiler. Crushed coal is fed to the pulverizing mill at a variable rate governed by the combustion requirements of the boiler and furnace. After milling, he coal dust or fuel is extracted from the pulverizer via a separator by an exhauster fan which discharges it to the burners with either hot air or flue gas. The secondary air is supplied to the burner before entering the fuel into the combustion chamber.

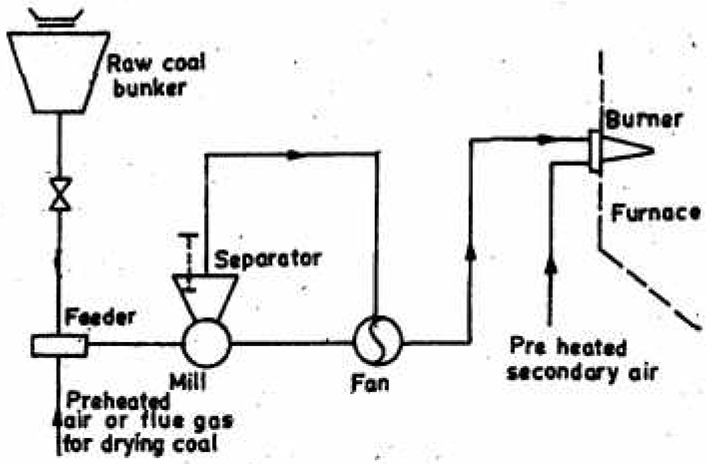


Fig. Pulverised fuel unit system

The advantages of unit system are :

1. It is cheaper than the central system since storage space or additional building is not required.
2. Layout is simple and permits of easy operation.
3. It allows direct control of combustion from the pulverizer.
4. Coal which would require drying in order to function satisfactorily in the central system, may usually be employed without drying in the unit system.
5. There is no complex transportation system.
6. No fire hazard is present owing to absence of pulverized fuel storage in the boiler room.
7. Lower maintenance charges.
8. The power consumption per ton of coal is usually slightly less.

Disadvantages :

1. In case of failure of the auxiliaries of one of the burner, the burner has to be put off as there is no reserve capacity maintained in this case.
3. The coal preparation plant of pulverizer has to operate under fluctuating conditions in accordance with the variation of boiler load demands. The maximum load for this plant coincides with the station maximum load, and extra generating plant is therefore necessary.
3. The degree of flexibility is less than the central system, although it is some what improved by using two or three units per boiler.

4. Exhauster fans handle air and pulverized coal, the latter causing excessive wear.

5. Large amount of wear takes place in coal preparation plant with reduces outputs and fineness. After long working periods this will result in the considerable reduction of boiler output and efficiency.

6. Strict maintenance is required as the operation of the plant directly depends upon the pulverizing mill, which has limited fuel capacity.

Q. 3. Draw a line diagram of the following coal based combined cycle plants :

(a) PFBC based combined cycle.

(b) Integrated gasification combined cycle.

Ans. Gas turbines after several advantages for different type of service peak load, emergency standby, base load, hydrostation stand-by etc. In some of these services the quick starting ability makes the gas turbine plant desirable.

The combination gas turbine-stamp turbine cycles aims at utilizing the heat of exhaust gases from the gas turbine and thus, to improve the overall plant efficiency. The heat content of gas turbine exhaust is quite substantial. Gas turbine exhaust has a temperature of around 500°C. The oxygen content in this exhaust has a temperature of around 500°C. The oxygen content in this exhaust is around 16% compared with 21% in atmospheric air. A simple cycle gas turbine plant wastes this energy to atmosphere, while a regenerative gas turbine plant recovers much of this heat to raise overall thermal efficiency. But instead we can use the gas turbine exhaust as a heat source for a steam plant cycle.

The combination steam and gas turbine cycle provides the highest efficiency turbine system available at the present time. The efficiency of the combined cycle is higher than efficiency of a standard regenerative cycle gas turbine.

There are three popular design of the combination cycles :

1. Gas turbine exhaust gases used for feed water heating,
2. Employing the exhaust gases as combustion air in the steam boiler, and
3. Employing the gases from a supercharger boiler to expand in the gas turbine.

Fig. shows a combined cycle in which the gas turbine exhaust passes through a heat exchanger to feed water for the boiler of the system plant. When this arrangement is used, bleeding of steam from the steam turbine (for the purpose of fed water heating) is not necessary. The full steam supply to the steam turbine is available for expansion and producing mechanical power.

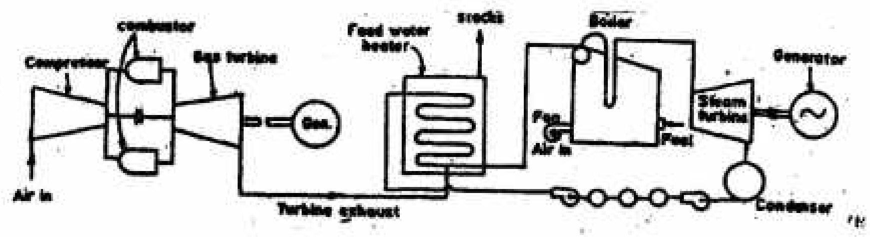


Fig. Use of exhaust gases to heat feed water of steam cycle

If bleeding is also used, the requirement of bled steam is much less than what would be required when no feed water heating with exhaust gases is employed. Arrangement is shown in figure, using both exhaust gases and bled steam for the feedwater heating. Further the gas inlet temperature to turbine can be increased and this results in an overall increase in efficiency of the plant.

Fig. shows a combined cycle in which the gas turbine exhaust is used as preheated air for the boiler of the steam plant.

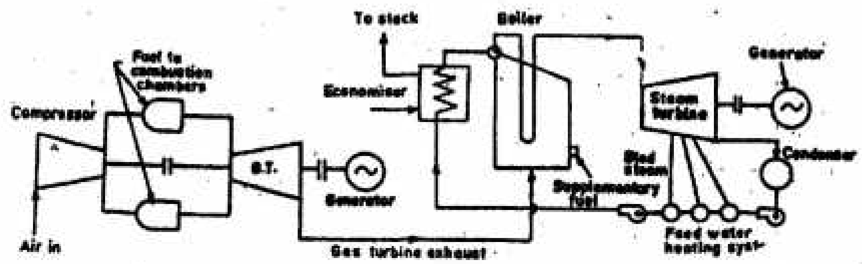


Fig. Combined gas and steam plant

The gas turbine exhaust has around 16% oxygen which is enough to support combustion in the boiler. Supplementary fuel and air can be fed to the boiler, which would be larger than the conventional boiler. About 5% improvement in plant heat rate can be obtained by the use of combined cycle.

(b) Peak load gas turbine power plants :

These power plants are mainly simple cycle gas turbine power plants because of their shorter gestation period, low cost of installation and fast starting characteristics though their thermal efficiency is relatively unfavourable. All large load centres in India, need this type of power plants to stabilize the grid when frequency is falling either due to overdrawing of power or less feeding to grid due to failure of few operating power plants. These power plants can also rectify the complete grid failures very quickly since they can achieve their full load within 20 minutes restoring partial. Supply to the grid catering to essential load requirements and to restart the tripped power plants. Gas turbine units operating on simple cycle will be the ideal solution to act as spinning reserve to cater to peak demand and demand-fluctuations of the grid.

The primary fuel for these plants will be gas or liquid fuel. The generator of these gas turbine power plants can also be utilised as synchronous condenser to improve power factor of the grid, when gas turbine power plants are not generating power.

Captive power combined cycle power plants :

When unit capacities are below 100 MW, combined cycle power plants are best suitable to generate electricity at lesser cost and than coal fired conventional thermal power plants even at existing liquid/gaseous fuel prices in India due to their higher efficiency of the order of 40-45%, low cost of installation/kW and high reliability. At present, unit capacities of the order of 100 MW and below are being mainly installed as captive power plants since most of the regional grids in India can accommodate larger size single unit of 200 MW and more.

Retrofitting of old and uneconomical power plants :

Some of the power plants which can not generate electricity at economical cost due to their less design thermal efficiency can be converted into combined cycle power plants. This modification can be done by replacing the existing steam generation by HRSG (Heat recovery steam generator) and Gas Turbine, such that existing steam cycle facilities can be utilised as bottoming cycle to the gas turbine. Sometimes, it is also possible to use Gas turbine exhaust gases as a practical source of heat energy in already existing coal fired steam generator by doing moderate alternations in the steam generator.

Q. 4. (a) Mention all the advantages and limitations of a nuclear power plant type of reactor used.

Ans. The main advantages of nuclear power station compared to the conventional thermal power stations are :

1. It reduces the demand for coal, oil and gas, the costs of which are tending to rise as the stocks become depleted. The amount of fuel used in the plant is small. Greater nuclear power production leads to conservation of coal oil etc.
2. Since the amount of fuel needed is small, there are no problems of fuel transportation, storage etc. It has been found that one kilogramme of Uranium can produce, as much energy as can be produced by burning 4500 tonnes of high grade coal.
3. Nuclear power plant requires less space compared to any other plant of the equivalent size.
4. Besides producing large amounts of power, the nuclear power plant can produce valuable fissile material, which is extracted when the fuel has to be renewed.
5. Bigger capacity of these plants is an additional advantage.
6. Nuclear plants create no smog, and are unaffected by adverse weather conditions.
7. Greater nuclear power production leads to conservation of coal, oil etc.

Limitations of the nuclear power plants include danger of radioactivity, detrimental working conditions to health of workers the problem of disposal of radioactive waste, high salaries of trained personnel etc.

Nuclear power plants can be used as base load plants. They are not suitable for variable load operation as the reactors cannot be easily controlled to respond quickly to load changes. They are used at a load factor of not less than 80 per cent.

The initial capital cost of nuclear power plants is very high only very few countries in the world possess the technology to manufacture nuclear reactors and nuclear fuel. Inspite of this, nuclear power is likely to supply greater and greater portion of future power needs of the world.

Q. 4. (b) Write the name, location, and capacity of all the nuclear power plants installed in India till date.

Ans. World's first nuclear power station was commissioned in 1954 in U.S.S.R. Dr. H.J. Bhabha is pioneer in this field for India to start nuclear power for peaceful purposes. BARC (Bhabha Atomic Research) Centre) is the major centre for research and development work in nuclear energy.

India at present has five nuclear power plants. First nuclear power plant was started at Tarapur. It has two boiling water reactors (BWRs) each of 200 MWe capacity and each uses enriches uranium as fuel. Second nuclear plant is at Rana Pratap Sagar Kota (Rajasthan), 400 MWe capacity, using CANDU type reactor. Third unit is at Kalpakka, 400 MWe capacity CANDU type reactor. Fourth is at Narora (U.P.) where two nuclear reactors each of 600 MWe capacity are being installed. Fifth is at Kakrapar near Surat (Gujarat) CANDU reactor, has four units of 235 MWe each, are being installed.

A power plant is proposed to be built in Bihar.

Q. 4. (c) Differentiate sodium graphite and fast breeder reactors.

Ans. Liquid metal-cooled reactors :

High temperatures are always desirable in all thermal plants to increase the efficiency of a power plant. The excellent heat transfer characteristics and heat transfer capacity of liquid metals make them potentially attractive as reactor coolants. The liquid metal coolant can be circulated through the reactor at moderate pressure and yet have temperature as high as 540°C. Therefore, it is possible to achieve low cost power with metal cooled reactor. The arrangement of the components of a metal-cooled reactor is shown in fig. 10. In which little enriched uranium is used as fuel, graphite as moderator and sodium as coolant.

The common metals which can be used as coolant are sodium and potassium. The eutectic alloy of these metals is also used for convenience, since it exists in liquid form at room temperature. However, sodium is best suited as coolant as it has low absorption cross-section (0.5 to 2 barns); low melting point (98°C), high boiling point (883°C), high specific heat (1.2 kJ/kg/°C), high thermal conductivity (120 times of water) and considerably cheap.

The advantages and disadvantages of metal-cooled reactors are listed below :

Advantages :

1. High temperatures can be achieved in the cycle and that means high thermal efficiency at low cost and low cost power.
2. The sodium as a coolant need not be pressurised.
3. The neutron absorption cross-section of sodium is low and, therefore, it is best suited to thermal reactor with slightly enriched fuel.
4. The low cost graphite moderator can be used as it can retain its mechanical strength and purity at high temperatures.

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5. In other reactors, the loss of coolant increases the reactivity because of the removal of neutron absorber. In such cases, the reactor must be shut down by safety rod otherwise it may cause severe overheating. The metal-cooled reactor is more stable from safety point of view as the reactivity decreases with the rise in temperature.

6. The reactor size is comparatively small.

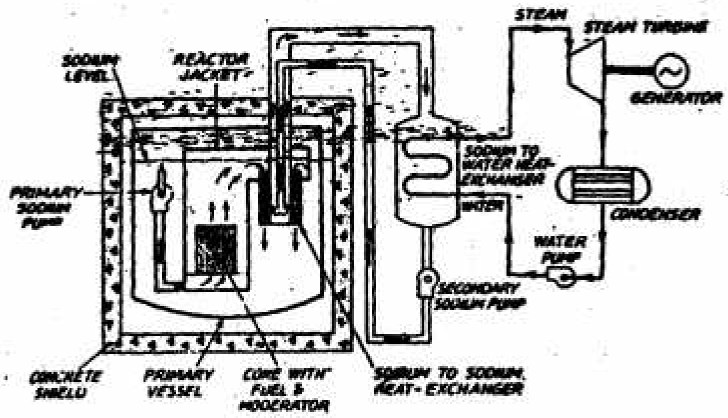


Fig. Sodium cooled reactor

Disadvantages :

1. The neutron economy is reduced with an increase in temperature because, the high energy neutrons are subjected to resonance peaks when the moderator is hot and increases the chances of non-fissionable absorption of neutrons.

2. It is always necessary to keep the graphite and sodium separate as porous graphite may absorb sodium and increase the absorption capacity of the graphite. The penetration of sodium between the layers of graphite can cause mechanical failure, therefore, each block of graphite is provided with a cladding which increases the construction cost.

3. It is necessary to shield the primary and secondary cooling systems with concrete block as sodium becomes highly radio-active due to neutron bombardment.

4. The leak of sodium is very dangerous compared with other coolants as it comes out of reactor in highly radioactive state.

5. A precaution must be taken to see that sodium does not come in contact with water as it becomes highly reactive forming caustic soda with the evolution of heat.

The experimental sodium-cooled reactor plant of 5.7 MW capacity at Santa Surna, California (U.S.A.) is an example of this type.

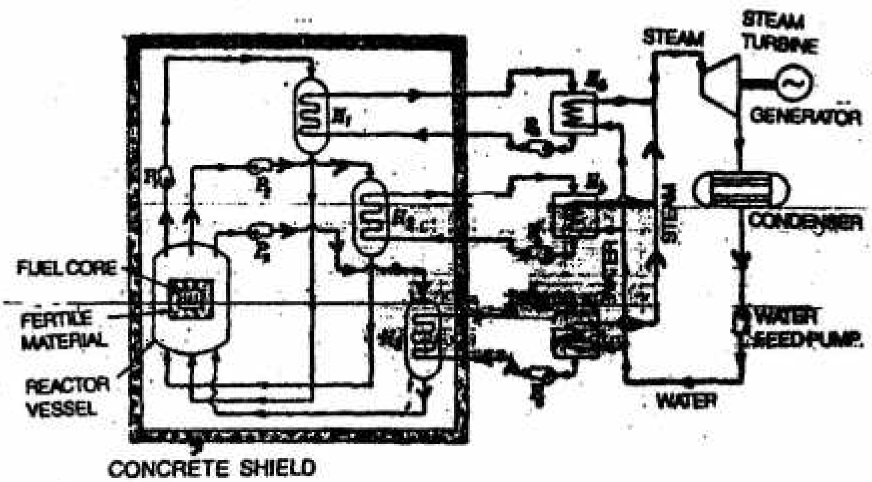
Fast breeder reactor :

In fast breeder reactor, an enriched uranium or plutonium (upto 10%) is kept in the casting without moderator. The casting is surrounded by failry thick blanket of depleted fertile uranium. The ejected excess-neutrons are absorbed by the fertile blanket and it converts into fissile material. The heat produced in the reactor core is carried by liquid metal. The arrangement of Fermi fast breeder reactor is shown in fig.

The Fermi-fast breeder reactor located at Lagoonal Beach, Detroit, Michigan in U.S.A. is first fast breeder reactor of the world. Enriched uranium was used as fissile fuel and depleted uranium as breeding material. The total power output was 94 MW electrical at an efficiency of 31.3%.

The major advantage of fast breeder is at high energies, the structural materials of the reactor do not absorb neutron, therefore, a wide choice of constructional materials is possible.

The major difficulty is to remove the large quantities of heat from the core as the power density is as high as 430 kW per litre of core volume which is 40 times greater than Candu type, 13 times greater than BWR and 200 times greater than gas-cooled reactor. Therefore, special coolants and special arrangements are necessary to carry out large quantity of heat.



Concrete shield

P_1, P_2, P_3 → Primary circuit sodium circulating pumps.

P_a, P_b, P_c → Secondary circuit sodium circulating pumps

H_1, H_2, H_3 → Primary sodium to sodium heat exchanger.

H_a, H_b, H_c → Secondary sodium to water heat exchangers.

Fig. Fermi-fast breeder reactor

Q. 5. (a) The input-output curve of 20 MW generating station is given by the following equation :

$$I = \left(7.5 + 0.125L + 0.16L^2\right)10^6$$

Where I is in kcal/hr and L is in MW. Find the average heat rate of this station for a day when it was operating at a load of 20 MW for 16 hours and was kept hot at zero for the remaining 08 hours. Find the saving in the heat rate if the same energy is produced for the whole day at 100% load factor.

Ans. $I = \left(7.5 + 0.125L + 0.16L^2\right)10^6$

At $L = 0$

$$I_0 = [7.5 + 0.125(0) + 0.16(0)] \times 10^6$$

$$= 7.5 \times 10^6 \text{ kcal / hr}$$

At $L = 20$

$$I_{20} = \left[7.5 + 0.125(20) + 0.16(20)^2\right] \times 10^6$$

$$= 74 \times 10^6 \text{ kcal / hr}$$

Total energy generator $= 20 \times 16 + 0 \times 8$

$= 320$ MWhr

Total input $= [7.5 \times 8 + 74 \times 16] \times 10^6$ kcal

$= 1244 \times 10^6$ kcal

$\therefore$ Average heat rate $= \dfrac{\text{Total input}}{\text{Total output}}$ for a given time

$$= \frac{1244 \times 10^6}{320} = 3.88 \times 10^6 \text{ kcal / hr}$$

In the second case when same energy is produced at constant load in 24 hrs.

$$\text{Average load } = \frac{320}{24} = 13.33 \text{ MW}$$

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Also at L = 13.33

$$I = \left[7.5 + 0.125L + 0.16L^2\right] \times 10^6$$

$$= \left[7.5 + 0.125(13.33) + 0.16(13.33)^2\right] \times 10^6$$

$$= 37.6 \times 10^6 \text{ kcal / hr}$$

Now heat rate

$$HR = \frac{I}{L} = \frac{37.6 \times 10^6}{13.33} = 2.82 \times 10^6 \text{ kcal / MW hr}$$

∴ The saving is

$$= (3.88 - 2.82) \times 10^6$$

$$= 1060000 \text{ kcal / kw hr}.$$

Q. 5. (b) The incremental fuel costs for two generating units A and B of a thermal power plant are given below:

$$\frac{dF_a}{dP_a} = 0.06\,P_a + 11.4,\ \frac{dF_b}{dP_b} = 0.07P_b + 10$$

P is in MW and F is in rupees/hour. Find the economic loading of he two units when the total load supplied by the station is 150 MW (ii) the loss in fuel cost per hour if the load is equally shared by the two units.

Ans. (i) The given data in

$$P_A + P_B = 150 \quad ...(1)$$

The condition required for economic loading

$$\frac{dF_A}{dP_A} = \frac{dF_B}{dP_B}$$

∴
$$0.06P_A + 11.14 = 0.07P_2 + 10 \quad ...(2)$$

Solving equations (1) & (2), we get

$$P_A = 70\,\text{MW}$$

$$P_B = 80\,\text{MW}$$

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(ii) If the load in equally shared by both units that is if each unit supplies 75 MW, then the increase in cost of find for unit A is given by

$$= \int_{70}^{75} [0.06P_A + 11.4] dP_A$$

$$= \left[0.03P_A^2 + 11.4P_A\right]_{70}^{75}$$

$$= \text{Rs. } 78.75 \text{ per hour}$$

Increase in cost for unit B

$$= \int_{80}^{75} (0.07P_B + 10)\, dP_B$$

$$= \left[0.035P_B^2 + 10P_B\right]_{80}^{75}$$

$$= -\text{Rs.}77.12 \text{ per}$$

The –ve sign indicates that there in decrease in cost. Hence net increase in cost due to departure from economic loading

$$= 78.75 - 77.12$$

$$= \text{Rs. } 1.63 \text{ per hour.}$$

Q. 6. Discuss the principle of MHD generation. How are MHD systems classified? Describe them in brief.

Ans. M.H.D power generation :

Introduction :

Eighty per cent of total electricity produced in the world, is hydal, while remaining 20 per cent is produced is produced from nuclear, thermal, solar Geothermal energy and from magneto Hydro Dynamics (MHD) generators. MHD power generation is a few systems of electric power generation which is said to be of high efficiencies and low pollution. In advanced countries MHD generators are widely used but in developing countries like India it is still under construction. This construction work is in progress at Trichi in Tamilnadu, under joint efforts of BARC (Bhabha Atomic Research Centre), BHEL, Associated Cement Corporation (ACC) and Russian Technologies.

As its name implies magneto hydro dynamics (MHD) is concerned with the flow of a conducting fluid in the presence of magnetic and electric field. The fluid may be gas at elevated temperature or liquid metal-like sodium or potassium.

An MHD generator is a device for converting heat energy of a fuel directly into electrical energy without a conventional electric generator. In this respect, an MHD converter system is a heat engine, in which heat taken up at a higher temperature is partly converted into useful (electrical) work and the remainder is rejected at a lower temperature. Like all heat engines, the thermal efficiency of an MHD converter (i.e., the proportion of the heat take up that is converted into useful work) is increased by supplying the heat at the highest practical temperature and rejecting it at the lowest practical temperature.

MHD generation looks the most promising of the direct conversion techniques for the large scale production of electric power. It is observed that economic and physical factors will lead to design outputs of the order of 1000 MW. In act MHD is really of interest only for central power generation; its potentialities for a propulsion unit are remote.

Principles of MHD generation :

The principle of MHD generation is simply that discovered by Faraday : when an electric conductor moves across a magnetic field a voltage is induced in it which produces an electric current. This is the principle of the conventional generator also where the conductors consists of copper strips. In the MHD generator the solid conductors are replaced by a gaseous conductor; an ionized gas. If such a gas is passed at a high velocity through a powerful magnetic field, a current is generated and can be extracted by placing electrodes in a suitable position in the stream. This arrangement is illustrated in fig., provides d.c. power directly.

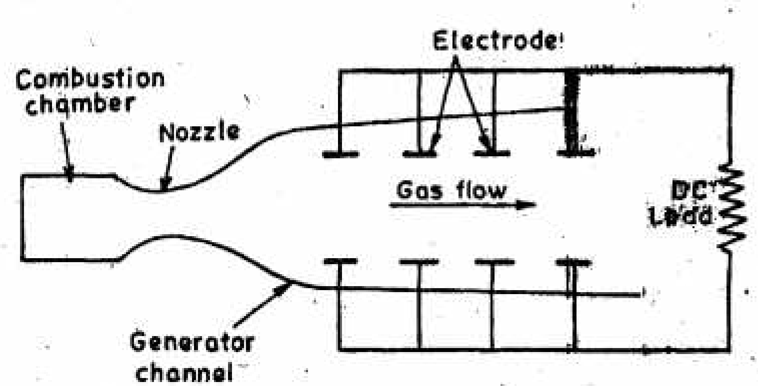


Fig. Simple MHD Generator

The direct conversion of kinetic energy into electrical energy by the flow of an electrically conducting fluid, usually, a gas or a gas liquid combination, through a stationary magnetic field. If the flow direction is, at right angles to the magnetic field direction, an electromotive force (or electrical voltage) is induced in the direction at right angles to both flow and field directions, as shown in figure. This is the basic principle of magneto hydro dynamics (MHD) conversion.

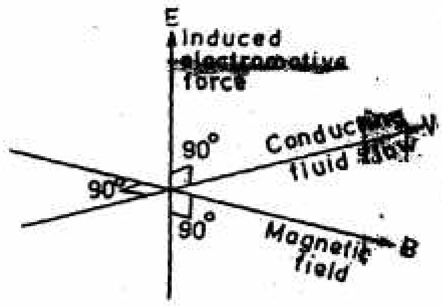


Fig. Principle of Magneto hydrodynamic conversion

Copper is a good conductor of electricity but gases are not good conductors their electrons are tied-up in electrically neutral particles.

But there is a way to turn a gas into conductor, dislodging its electrons by ionizing it. If the gas is heated to a high temperature, it gets converted into plams and plasma is conductor of electricity. The level of ionisation in plasma decides its conductivity. To raise the conductivity of the gas, it is 'seeded' with a metal like potassium.

In a practical MHD converter or generator, the energy of motion of the conducting fluid is derived from heat obtained by burning a fossil fuel. Hence an MHD generator is a device for converting heat energy directly into electrical energy (without a conventional electric generator).

In MHD schemes under study, the working fluid usually consists of a carrier gas which is itself a non-conductor, it is rendered electrically conducting in two different ways, one way is to inject a solid 'seed' material into the gas, upto about 1 per cent of the total flow rate. The seed contains an element, commonly potassium, which ionizes when heated, that is to say, the atoms of the seed element split off electrons. The presence of the negatively charged electrons makes the carrier gas an electrical conductor. The other way is to incorporate a liquid metal into a flowing carrier gas, i.e., gas metal mixture can be used as working fluid.

The gas experiences a breaking force due to electromagnetic interaction, which can be compared to the retarding force produced by the turbine blades in the conventional system. As mentioned above, the gas must be ionized, in order that it may conduct sufficiently for successful operation. In practice the degree of ionization required is very small (0.1%), so the gas is still composed mostly of natural particles. It is these neutral particles that carry nearly all the KE of the stream and of course they are unaffected by electromagnetic forces. The exact mechanism of the breaking force has not yet been explained, but it is true that the force that it exerts on the electrons in the gas. The force is then coupled to the neutral particles by the electron ion coulomb forces and the ion-neutral collisions. The retarding force will thus be a complex function of collision cross-sections and magnetic field density.

MHD systems can be classified broadly as follows :

1. Open cycle systems.
2. Closed cycle systems.
   (i) Seeded inert gas systems
   (ii) Liquid metal systems.

1. Open cycle MHD :

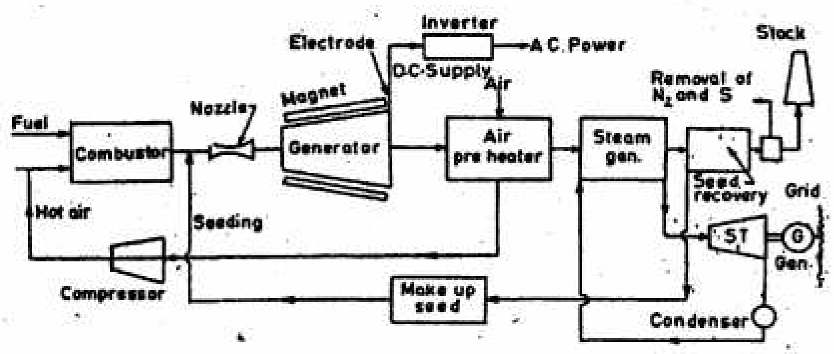


Fig. Schematic of an open cycle MHD generator

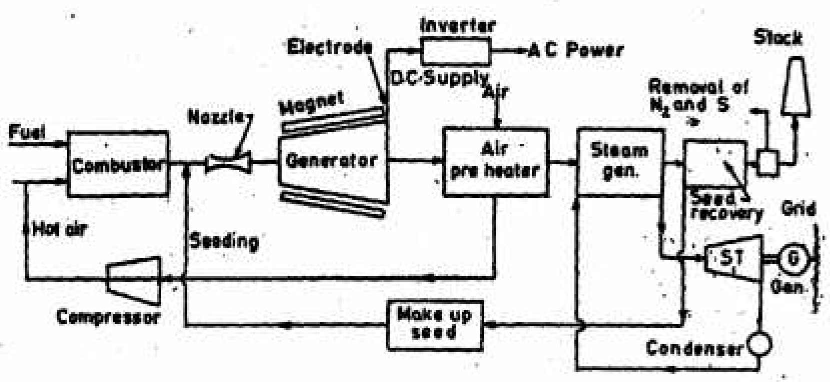
The arrangement of the system is shown schematically in fig. In this system, fuel used may be oil through an oil tank or gasified coal through a coal gasification plant fuel (coal, oil or natural gas) is burnt in he combustor or combustion chamber. The hot flue gas from the combustor is then seeded with a small amount of an ionized alkali metal (cesium or potassium) to increase the electrical conductivity of the gas. The seed material generally potassium carbonate is injected into the chamber; the potassium is then ionized by the hot combustion gases at temperatures of roughly (2300 to 2700°C).

To attain such high temperatures, the compressed air used to burn the coal (or other fuel) in the combustion chamber must be preheated to atleast (1100°C). A lower preheat temperature would be adequate if the air were enriched in oxygen. An alternative is to use compressed oxygen alone for combustion of the fuel; little or no preheating is then required. The additional cost of the oxygen might be balance by the savings on the preheater. The hot, pressurized working fluid leaving the combustor flows through a convergent-divergent nozzle similar to a rocket nozzle. In passing through the nozzle, the random motion energy of the molecules in the hot gas is largely converted into directed mass motion energy. Thus, the gas emerges from the nozzle and enters the MHD genertor unit at a high velocity.

2. Closed cycle MHD :

Two general types of closed cycle MHD generators are being investigated. In one type, electrical conductivity is maintained in the working fluid by ionization of a seed material, as in open-cycle systems; and in the other, a liquid metal provides the conductivity. The carrier is usually a chemically inert gas, although a liquid carrier has been used with a liquid metal conductor. The working fluid is circulated in a closed loop and is heated by the combustion gases using a heat exchanger. Hence, the heat source and the working fluid are independent. The working fluid is helium or argon with cesium seeding.

In a closed-cycle system the carrier gas (argon/helium) operates in a form of ray ton cycle. The gas is compressed and heat is supplied by the source, at essentially constant pressure; the compressed gas then expands in the MHD generator and its pressure and temperature fall. After leaving the generator, heat is removed from the gas by a cooler; this is the heat rejection stage of the cycle. Finally the gas is recompressed and returned for reheating.



Closed Cycle MHD System

1. Seeded inert gas system :

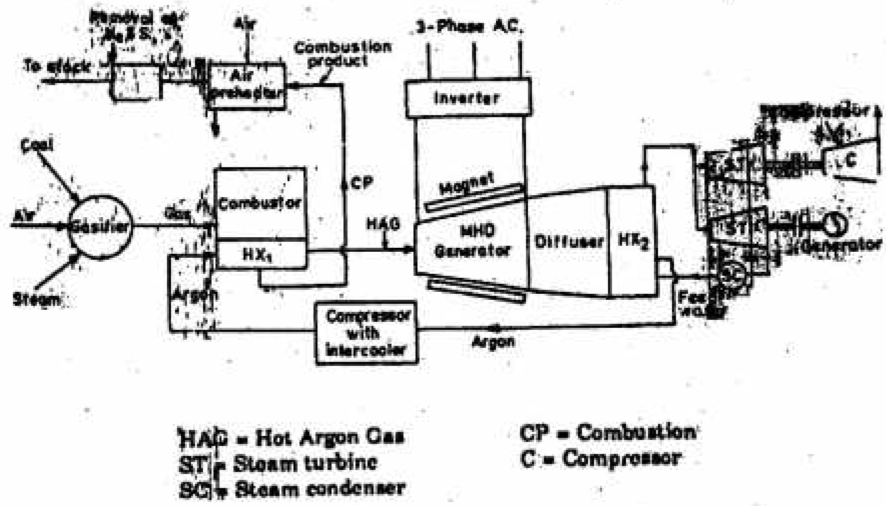


Fig. Closed cycle MHD System

A closed cycle MHD system is shown in fig. The complete system has three distinct but inter locking loops. On the left is the external heating loop. Coal is gasified and the gas (having a high peak value of about 5.35 MJ/kg and at a temperature of about 525°C) is burnt in a combustor to produce heat. In the primary heat exchanger, this heat is transferred to a carrier gas (argon/helium working fluid) of the MHD cycle. The combustion products after passing through the air preheater (to recover a part of the heat of combustion products) and purifier (to remove harmful emissions) are discharged to atmosphere. Because other combustion system is separate from the working fluid, so also are the ash and flue gases. Hence, the problem of extracting the seed material from flyash does not arise. The flue gases are used to preheat the incoming combustion air and then treated for flyash and sulfurdioxide removal, if necessary, prior to discharge through a stack to the atmosphere.

Q. 7. (a) Describe open cycle OTEC plant with the help of flow diagram. What modifications can be carried out to the open cycle OTEC plant to make it economically feasible?

Ans. Open and closed cycles :

There are two rather different methods for harnessing ocean thermal differences. One is the claude cycle or open cycle and other is the closed cycle system.

The claude cycle or open cycle which is older one, utilizes the vapour pressure of sea water itself as the working medium and has been demonstrated to be practicable. The other method a closed cycle known as the Rankine cycle, uses a working fluid with higher vapour pressure (such as ammonia, hydrocarbon or halocarbon) at the temperature available. This cycle is favoured for the future development in expectation of higher efficiency.

In the closed-cycle system (fig.), a liquid working fluid, such as propane or ammonia is vaporised in an evaporator (or boiler); the heat required for vaporization is transferred from the warm ocean surface water to the liquid by means of a heat exchanger.

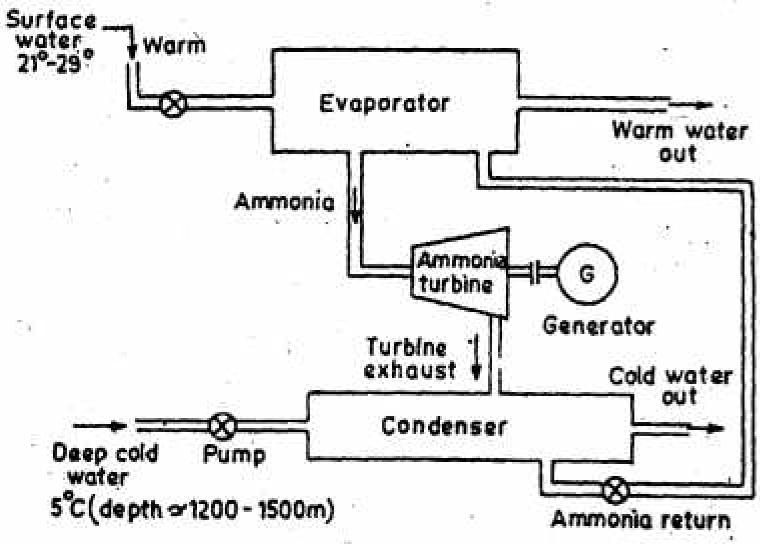


Fig. Schematic at a closed OTEC ammonia cycle

The high-pressure vapour leaving the evaporator drives an expansion turbine, similar to a steam turbine except that it is designed to operate at a lower inlet pressure. The turbine is connected to an electrical generator in the usual manner. The low-pressure exhaust from the turbine is cooled and converted back into liquid in the condenser. The cooling is achieved by passing cold, deep ocean water, from a depth of about 1200 m, or more, through a heat exchanger. The liquid working fluid is then pumped back to the evaporator, thus closing the cycle.

Open cycle refers to the utilization of sea water as the working fluid, wherein sea water is flash evaporated under a partial vacuum. The low pressure steam is passed through a turbine, which extracts energy from it, and then the spent vapour is cooled in a condenser. This cycle derives the name 'open' from the fact that the condensate need not be returned to the evaporator, as in the case of the 'closed cycle'. Instead, the condensate can be utilized as desalinated water if a surface condenser is used or if a spray (direct-contact) condenser is used, the condensate is mixed with the cooling water and the mixture is discharged back into the ocean. A schematic diagram of the open cycle system is shown in fig. Since the early OTEC experiments performed by claude utilized an open cycle, the open cycle system is sometimes referred to as a 'Claude Cycle.'

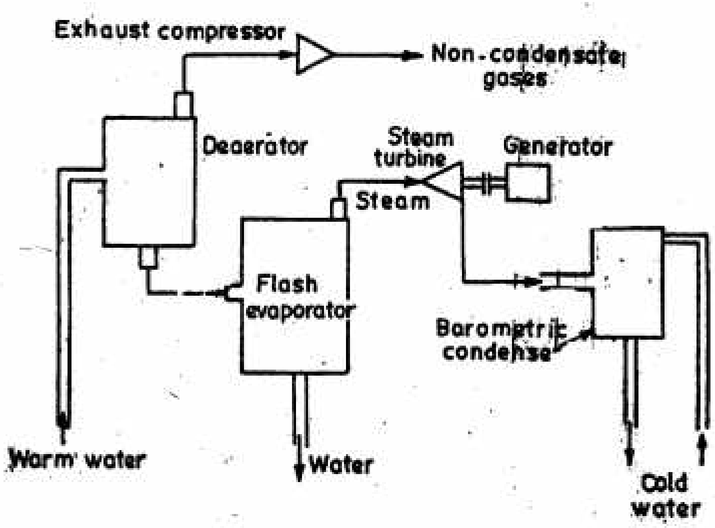


Fig. Schematic of the OTEC open cycle

Because of the need in the open cycle to harness the energy in low-pressure steam, extremely large turbines must be utilized. Furthermore degaussers (de aerators) must be used to remove the gases dissolved in the sea water unless one is willing to accept large losses in efficiency. On the other hand, since there are no heat transfer problems in the evaporator, the problem of bio-fouling (layer of slime accumulation) control is minimized.

The cost of an open cycle system for producing substantial number of megawatts is presently regard by most OTEC workers as being significantly greater than for closed-cycle system. The turbine cost constituted almost half the cost of the power system, but may be amenable to reductions that could result from design innovations.

Although both closed and open cycle turbine systems are being explored, it appears that closed-cycle systems offer the most promise for the near future. Each of the possible working fluids (i.e., ammonia and propane) has advantages and disadvantages. Ammonia has better operating characteristics than propane and it is much less flammable. On the other hand ammonia forms a noxious vapour and probably could not be used with copper heat exchangers propane compatible with most heat-exchangers materials, but it is highly flammable and forms an explosive mixture with air. Ammonia has been used as the working fluid in successful tests of the OTEC concept with closed-cycle systems made near the Hawaiian Islands.

Q. 7. (b) Describe the principle and applications of solar ponds and solar collectors.

Ans. Solar ponds :

The solar pond combines solar energy collection and sensible heat storage. The energy is stored in low grade (60 to 90°C) thermal form, which might be suitable for a variety of applications such as space heating and industrial process heat. Alternately, organic Rankine cycle engines can be used to obtain mechanical and or electrical energy.

A solar pond is a mass of shallow water about 1 meter deep with a large collection area, which acts as a heat trap. It contains dissolved salts to generate a stable density gradient. Part of the incident solar radiation entering the pond surface is absorbed throughout the depth and the remainder which entreaties the pond is absorbed at the black bottom. Convention low is eliminated by initially creating a sufficiently strong salt concentration gradient. With convection suppressed, the heat is lost from the lower layers only by conduction. Because of tis relatively low thermal conductivity, the water acts as an insulator and permits high temperatures (over 90°C) to develop in the bottom layers. Energy can be extracted from the pond by receiving the water in the hot layers of the pond through a heat exchanger.

Depending on location; water clarity and temperature, the solar pond can capture 10 to 20 per cent of the solar energy hitting its surface. Hence, each square meter of pond surface area can supply one half to two giga joules of thermal energy per year at temperatures from 40 to 80°C. A flat plate collector of the same area would be twice as efficient but cost ten times as much.

Solar Collector :

A solar collector is a device for collecting solar radiation and transfer the energy to a fluid passing in contact with it. Utilization of solar energy requires solar collectors. These are general of two types :

(i) Non-concentrating or flat plate type, and

(ii) Concentrating or focusing type solar collector

The solar energy collector, with its associated absorber, is the essential component of any system for the conversion of solar radiation energy into a more usable form (i.e., heat or electricity). In the non concentrating type, the collector area (i.e., the area that intercepts the solar radiation) is the same as the absorber area (i.e., the area absorbing the radiation). On the other hand, in concentrating collectors, the area intercepting the solar radiation is greater, sometime hundreds of time greater than the absorber area. By means of concentrating collectors, much higher temperatures can be obtained than with the non-concentrating type. Concentrating collectors may be used to generate medium-pressure steam. They use many different arrangements of mirrors and lenses to concentrate the sun's rays on the boiler. This type shows better efficiency than the flat plate type. For best efficiency, collectors should be mounted to face the sun as it moves through the sky.

Q. 8. Write notes on the following :

(a) Selection of plants

(b) Advantages, disadvantages and applications of geothermal energy.

(c) Site section of thermal power plants.

Ans. (a) Selection of plants :

The type of power plant to be installed depends upon the source of energy. A hydroelectric power plant should be installed where sufficient head of water is available, whereas a steam power station is suitable near coal mines. Nuclear plant should be installed near a source of water for example river, lake, sea etc. Diesel plant is preferred for smaller loads. Further choice of the number of generating units should be made. If a system power plant of 200 MW capacity is to be installed than it is to be decided whether a single boiler will be supplying steam to a single turbine or three will be two units each of 100 MW capacity of four units of 50 MW each or there can be single boiler supplying steam to four turbines each of 50 MW capacity. Unit system in which a single boiler supplies steam to single turbine is preferable.

(b) Advantages and disadvantages of geothermal energy over other energy forms :

Advantages : This energy from possess some distinct advantages over conventional and other new energy sources.

1. Geothermal energy is versatile in its use.
2. It is cheaper-compared to the energies obtained from other sources both zero levels and fossil fuels.
3. Geothermal energy delivers greater amount of net energy from its system than other alternative or conventional systems.

4. Geothermal power plants have the highest annual load factors of 85 percent to 90 percent compared to 45 percent to 50 percent for fossil fuel plants.

5. Geothermal energy is the least polluting compared to the other conventional energy sources.

6. The greatest attraction of Geothermal energy is its amenability for multiple uses from a single resource.

7. This form of energy is available all the year round.

8. It is an inexhaustible source.

9. It is cheaper in production costs.

Disadvantages :

1. Overall efficiency for power production is low, about 15 percent, as compared to 35–40 percent for fossil fuel plants.

2. The withdraw of iarge amounts of steam or water from a hydrothermal reservoir may result in surface subsidence (settlement).

3. The steam and hot water guishing out of the earth may contain H_2S, CO_2, NH_3 and radon gas etc. If these gases are vented into the air, air pollution will be a real hazard. These gases are to be removed by chemical action, before they are discharged.

4. Drilling operation is noisy.

5. Large areas are needed for exploitation of Geothermal energy as much of it obtained as diffuse.

(c) Site section of thermal power plants :

The economics of electric power production and distribution make it essential that generation should be carried on in large central stations, the location of these, playing an important part in the cost of energy generated. The ideal position is at the centre of gravity of the 'loads' on the distribution system, thus avoiding very long transmission lines. The shortening of transmission lines and/or cables reduces the capital cost and losses associated with them, even with a lower thermal efficiency due to the use of cooling towers compared with a river side site some considerable distance from load centre. It should be pointed out that where a new station is an addition to an existing network its location may not be required to be near the load centre and the relative costs of energy transmission and coal transport are in this respect not nearly so important.

The general there are three choices :

1. At the load centre.
2. At or near the coal mine.
3. On an estuary site to which the coal can be delivered by sea.

The choice of the site may be dictated partly with the idea of obtaining adequate spare load in the vicinity of the station to which it may be possible to attract works requiring large power supply as a result of the advantageous terms which could be arranged.