Module 2 PGE (15EE361)

Steam Power Plants, Diesel power plant, Gas Turbine Power Plant

* Steam Power Plants :
* Introduction : The use of steam power started when it was first used in locomotives invented by James Watt. Thereafter, the steam power is used to rotate the prime mover of electric generator and it is known as steam power plant. In this process heat energy is converted into mechanical energy and then to electrical energy through turbine-generator system. Heat energy may be obtained by the proper combustion of a commercial fuel such as coal, gas, oil etc. Since abundant availability with reasonably no cost, water is used to generate steam, which readily conveyed through pipes, in a boiler by burning fuel in furnace. Steam power plants are also called thermal power plants. The prime movers of steam power plants may be operated either in noncondensing or condensing. In ~~other words~~ the noncondensing operation, the steam is exhausted from the prime movers and is discharged at atmospheric pressure or at greater than atmospheric pressure. where as in condensing plant, the prime movers exhaust discharge steam into a condenser in which the pressure is less than atmospheric and steam is converted into water. This is most commonly used in modern age power plants.

* Efficiency of steam power plants : The overall efficiency of a steam power station is quite low (about 29%) due to mainly two reasons. Firstly, a huge amount of heat is lost in the condenser and secondly heat losses occur at various stages of the plant. The heat loss in the condenser cannot be avoided. It is because heat energy cannot be converted into mechanical energy without temperature difference. The greater the temperature difference, the greater is the heat energy converted into mechanical energy. This necessitates to keep the steam in the condenser at the lowest temperature. But we know that, greater the temperature difference, greater is the amount of heat lost. This explains for the low efficiency of such plants.

i) Thermal efficiency : The ratio of heat equivalent of mechanical energy transmitted to the turbine shaft to the heat of combustion of coal is known as thermal efficiency of steam power station.

$$\text{Thermal efficiency, } \eta_{thermal} = \frac{\text{Heat equivalent of mechanical energy transmitted to turbine shaft}}{\text{Heat of coal combustion}}$$

The thermal efficiency of a modern steam power station is about 30%. It means that if 100 calories of heat is supplied by coal combustion, then mechanical energy equivalent of 30 calories will be available at the turbine shaft and rest is lost. It may be important to note that more than 50% of total heat of combustion is lost in the condenser. The other heat losses occur in flue gases, radiation, ash etc.

ii) Overall efficiency : The ratio of heat equivalent of electrical output to the heat of combustion of coal is known as overall efficiency of steam power station i.e

$$\text{Overall efficiency}, \eta_{overall} = \frac{\text{Heat equivalent of electrical output}}{\text{Heat of combustion of coal}}$$

The overall efficiency of steam power station is about 29%. It may be seen that overall efficiency is less than the thermal efficiency. This is expected since some losses (about 1%) occur in the alternator. The following relation exists among the various efficiencies.

Overall efficiency = Thermal efficiency × Electrical efficiency

* **Merits and Demerits of plants**

Merits :

i) The fuel (i.e coal) used is quite cheap.
ii) Less initial cost as compared to other generating stations.
iii) It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road.
iv) It requires less space as compared to the hydroelectric power station.
v) The cost of generation is lesser than that of the diesel power station.

Demerits :

i) It pollutes the atmosphere due to the production of large amount of smoke and fumes.
ii) It is costlier in running cost as compared to hydroelectric plant.

* **selection of site :**

Following are the factors to be considered for the site selection of thermal power plant and installation of its equipments.

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

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

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

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

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

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

* Working of steam plant :

A steam power station basically works on the principle of Rankin cycle. Steam is produced in the boiler by utilising the heat of coal combustion. Then the steam is conveyed to the prime mover (steam turbine) and it is condensed in a condenser to be fed into the boiler again. The steam turbine drives the alternator (electric generator) which converts the rotary mechanical energy into electrical energy. The prime movers of steam power plants may be operated either in non condensing or condensing.

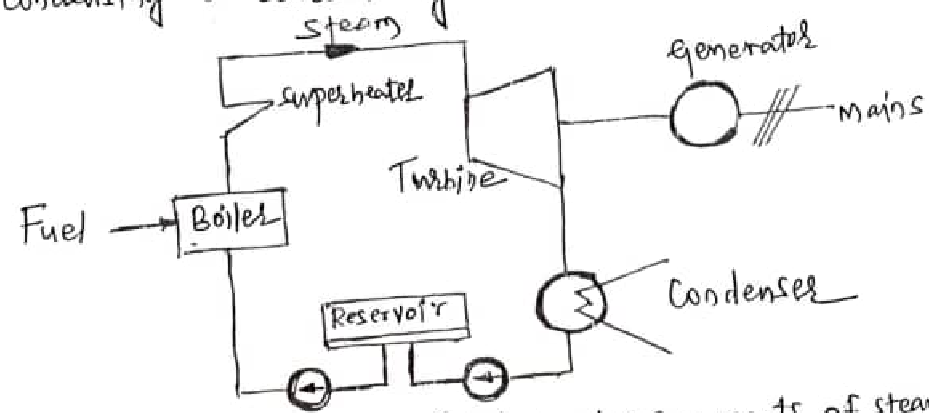

fig 1. Major components of steam power plant

* Power Plant Equipment and Layout :

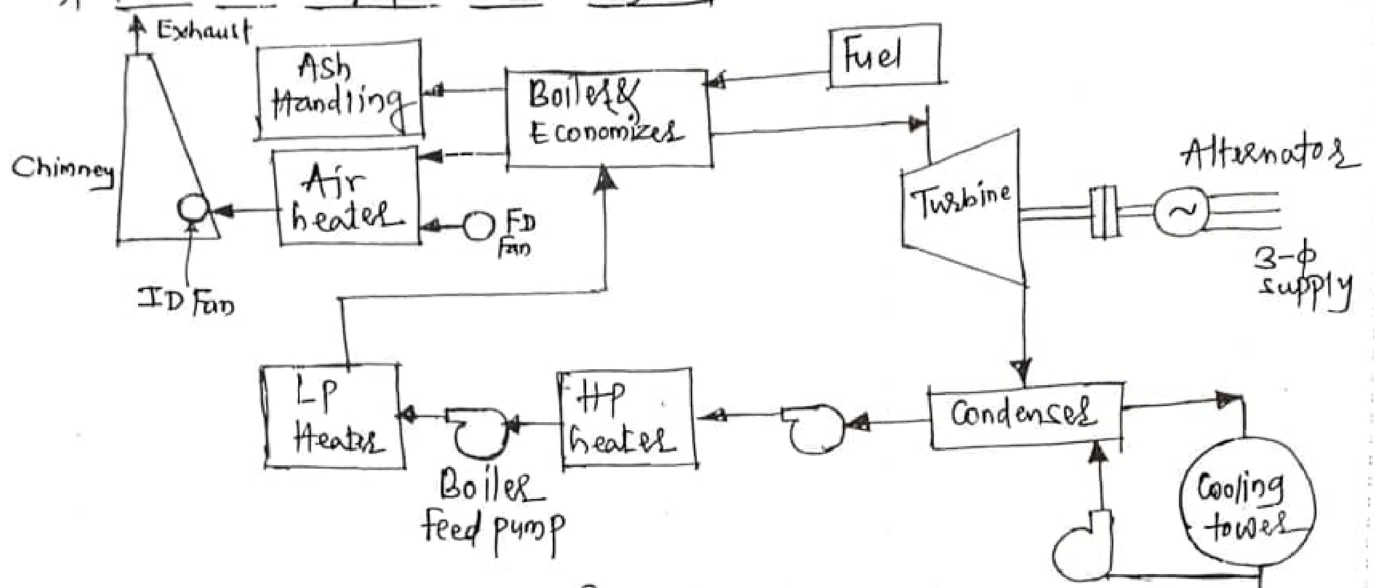

fig 2. Layout of typical steam power plant

Boiler : Boiler, which is the second tallest part after the chimney in a steam power plant, is used for producing the steam under pressure and reheating it, i.e heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature and pressure. The flue gases from the boiler makes their journey through superheater, economiser, air preheater and finally exhausted to atmosphere through the chimney.

Economiser : An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of heat of flue gases to increases the feed water temperature.

Air preheater : Since the entire heat of the flue gases cannot be extracted through the economisers, air preheaters are employed to recover some of the heat in these gases. It increases the temperature of the air supplied for the coal burning by deriving heat from the flue gases. Air is drawn from the atmosphere by a forced draught fan (FD) and is passed through air preheater before supplying to the boiler furnace. Aire preheater extracts heat from flue gases and increase the temperature of air used for coal combustion. The principal benefits of preheating the air are: increased thermal efficiency and increased steam capacity per square meter of boiler surface.

Superheaters and Reheaters : The steam produced in the boiler is wet and is passed through a superheater where it is dried and superheated (i.e., steam temperature increased above that of boiling point of water) by the the flue gases on their way to chimney. In otherwords a superheater is a device which removes the last traces of moisture (1 to 2%) from the

from the saturated steam leaving the boiler tubes, and by increasing its temperature sufficiently above saturation temperature. Superheating provides two principal benefits. Firstly, overall efficiency is increased. Secondly too much condensation in the last stages of the turbine (which would cause blade corrosion) is avoided. The superheated steam from the superheater is fed to steam turbine through the main valve.
(Note: ~~Hose~~ The steam that exists at the vaporization temperature corresponding its absolute pressure is defined as saturated steam, which may or may not carry water with it).
A Reheater is essentially a superheater as it is designed to bring the partially expanded steam back to superheat temperature by passing it through the tubes.

Steam prime mover (steam turbine): Steam turbines are usually employed as prime movers. The dry and superheated steam from the superheater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of the turbine is converted into rotational mechanical energy. In steam turbine the steam expands in the stationary nozzles and attains a higher velocity. There are several stationary blades and moving blades. The steam pressure is gradually reduced in the blades as the steam passes through them. After giving heat energy to the turbine, the steam is exhausted to the condenser.

Alternator: (synchronous generator): The steam turbine is coupled to an alternator. The alternator converts rotary mechanical energy of turbine into electrical energy. The electrical output from the alternator is delivered to the bus bars through transformer, circuit breakers & isolators.

Condenser: In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed by means of a condenser. Water is drawn from a natural source of supply such as a river, canal or lake and is circulated through the condenser. The circulating water takes up the heat ~~and is circulated~~ of the exhausted steam and itself becomes hot. This hot water coming out of the condenser is discharged at a suitable location down the river.
In case the availability of water from the source of supply is not assured throughout the year, Cooling towers are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled by dividing the water in smaller quantities practically of the size of drops. These water drops fall from a height of 8 to 10 meters to the bottom of the cooling tower. The cooled water from the base of cooling tower is reused in the condenser & the cycle is repeated.

* Steam turbines:

- The steam turbine has several advantages over steam engine as a prime mover. It has higher thermodynamic efficiency since steam can be expanded to a lower final temperature than its possible in a steam engine. The basic construction of a steam turbine is simple. There is no need of piston rod mechanism and slide valves; no flywheel is needed. Also steam turbine can be built in large sizes as much as 1000 MW. No-wearing action being involved maintenance of a steam turbine is comparatively much simple. Problems of vibrations is also much less since high operating speeds results in a lower weight of rotating parts for the same power.
- The steam turbines are generally of two types – impulse & reaction. In an impulse turbine the steam expands in the stationary nozzles and attains a higher velocity. Potential energy in steam due to pressure and internal energy is converted to kinetic energy when passing through the nozzles. There are a number of stationary blades and moving blades. A reaction turbine has no nozzles. This types of turbines also has fixed and moving blades. A partial drop of pressure is used to allow the steam into the moving blades. The pressure is gradually reduced in the blades as the steam passes through them. Commercial turbines use series combination of impulse and reaction types because steam can be used more efficiently by using impulse and reaction blading on the same shaft. The steam is expanded through the turbine from a high pressure at the throttle valve to a back pressure corresponding to a vacuum of 71 to 73.5 cm Hg or an absolute pressure of 5 to 2.5 cm Hg.
- Impulse or reaction or mixed arrangement of both these are the types of steam turbines used for power station purposes. The rotor shaft of the turbine is made of forged steel and the turbine blading is fixed on to it in the required number of stages. The blades are milled from solid steel blocks. The bottom and top halves of casing contain the stationary blades. Two to four extractions are usual though actual number depends on economic use of the bed steam for feed water heating or in evaporators.
- Vacuum in the condenser: A vacuum of 70-73.5 cm Hg i.e an exhaust pressure of 6 to 2.5 cm Hg (absolute) is aimed at. As high a vacuum in the condenser as possible is maintained for best working. In general high ~~turbine~~ capacity turbines maintain higher vacuum (73.5 cm Hg). Steam turbines used for power stations are condensing type. Surface condensers are used. Turbines with ratings upto 550 MW are available. While sizes upto 1000 MW are being designed and installed.
- Steam Consumption. Steam flow at any load

$$= \text{No load flow} + \left[\text{load} \times \frac{\text{Full load flow} - \text{No load flow}}{\text{Full load flow}}\right]$$

- Steam flow at no-load is 20-25 % of the full load steam flow for small steam turbines while for large stations the corresponding figure is 3 to 10 %.
- As a rough idea the steam consumption of large steam turbines is about 4 Kg/KWh (steam pressure atleast 42 kg. per cm^2 at a temperature of 440°C absolute pressure at exhaust 5 to 9.5 cm Hg)
- A typical approximate heat balance sheet for a large turbine and surface condenser taken together is as follows:

	Percent
Work done or thermal efficiency	28
Friction and windage loss	01
Heat to circulating water	65
Heat in condensate to be returned to boiler	06
	100 %

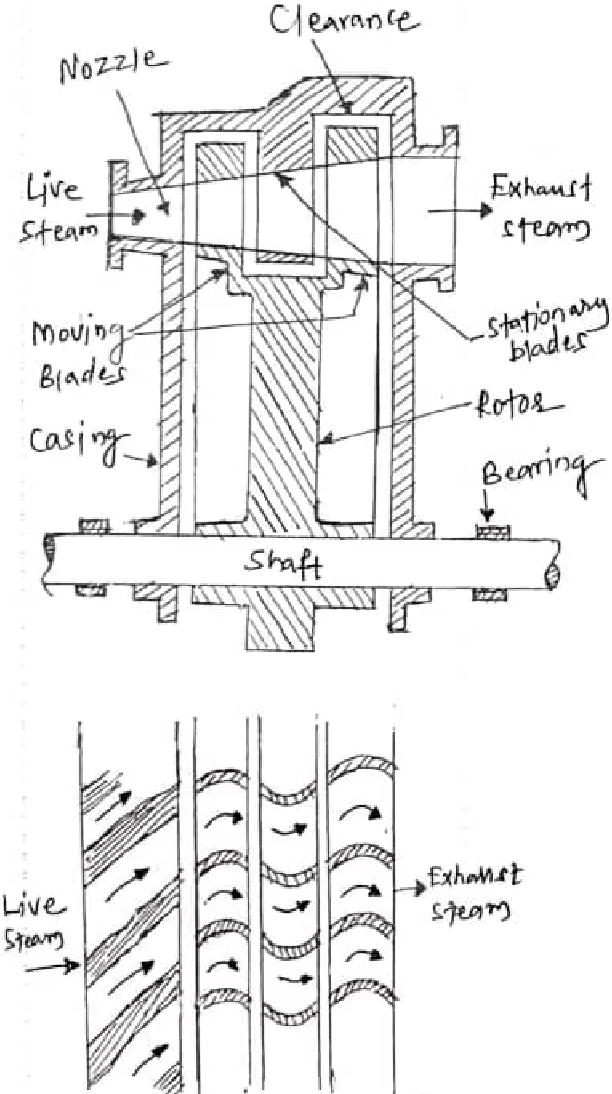

fig 3a An Impulse turbine

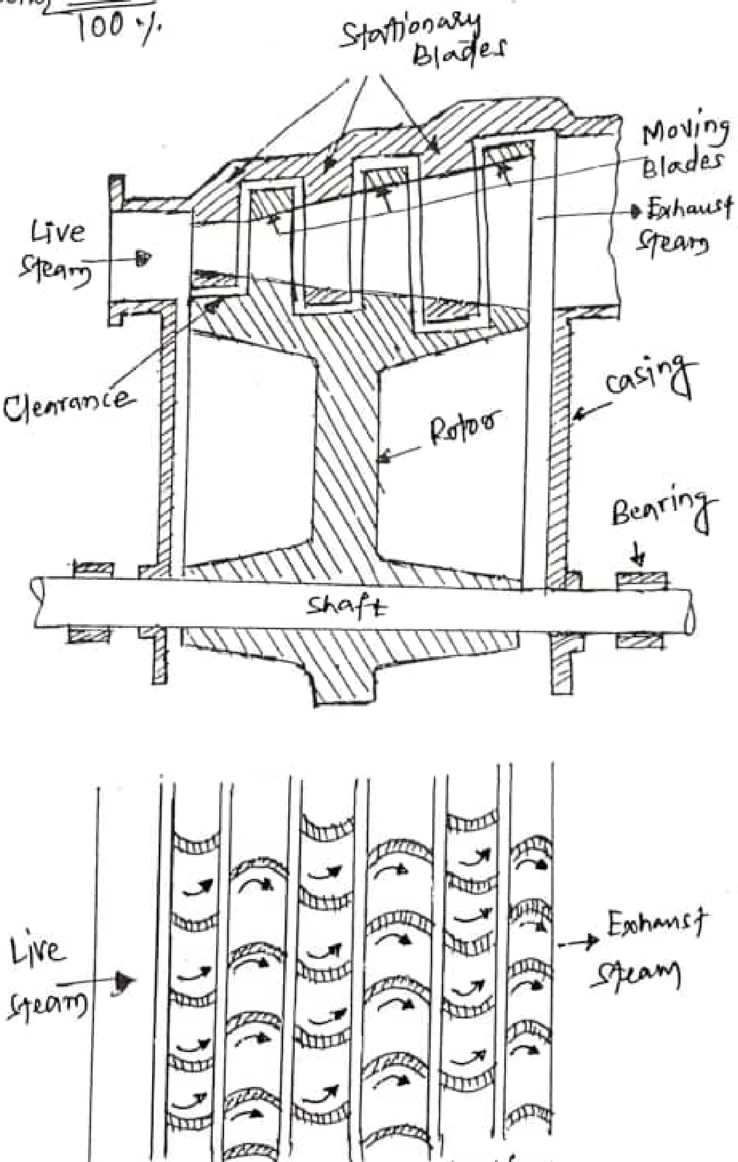

fig 3b. A reaction turbine

* Fuels and Fuel handling :

Fuels : Fuels may be classified as solid, liquid and gaseous and as natural or prepared. Fuel normally used in a thermal station is coal, oil or gas. Gaseous fuels is rarely economical except in special circumstances where it may be available very cheaply on site. oil also is used only where it is plentiful and cheap. Coal is the fuel used most commonly in a thermal station (steam power station).

- Coal occurs naturally in seams and is the result of decay of vegetable matter accumulated in the earth millions of years ago having got transformed by the action of pressure and heat. As mined raw coal usually contains impurities such as pieces of slate etc. with the result that some amount of processing is required at the colliery before it can be shipped.
- Analysis of coal : In order to find the commercial value of coal two tests are performed. The commonly used tests are proximate and ultimate analysis.

  proximate analysis : of coal gives good indication about heating & burning properties of coal. The test gives the composition of coal in respect of moisture, volatile matter, ash and fixed carbon.

  Ultimate analysis : is a test that enables us to know the chemical composition of coal with respect to elements like carbon, hydrogen, oxygen, sulphur, nitrogen and ash. Neverthe-less the chemical composition is very useful in combustion calculations and in finding the composition of flue gases. For the most purposes the proximate analysis is quite sufficient.
- Classification of coals : Coals are classified in increased ~~values~~ order of heat value in the following : Peat, lignite, bituminous, semi-bituminous, semi-anthracite & anthracite. Anthracite is the fully transformed coal of the best type while peat is the first stage of this transformation. The other varieties represent intermediate stages.
- Indian Coals : In general these coals have high ash content and the ash is finally disseminated through the coal so that cleaning of coal is a difficult and costly process. washing of coal to reduce the ash content is necessary to obtain low ash metallurgical coal. Average ash content in indian coal is as high as 20%. and ash content of middlings at coal washeries lies between 30 and 40%. Recent indian power plants in India are generally designed to use pulverised coal, as in that form of coal thermal efficiency may be as high as 90%.

- Liquid fuels : oil can be used in a boiler furnace to generate steam, oil (alcohol, petroleum etc) used as a fuel It offers a number of advantages. However the great disadvantage of liquid fuels is that the heat produced is costly as compared with coal or gas. Moreover, in a country like India where natural resources of oil are in short supply application of oils for power production is limited. Further, as the fuel oil contains more percentage of hydrogen as compared to coal the moisture carried by the gas per kg of fuel burned is considerably more. This results in lower overall combustion efficiency of the plant as compared to the coal burning.
- Gaseous fuels : These fuels are broadly divided into natural or manufactured. Natural gas comes out of gas wells and petroleum wells. It contains 60 to 95 % of methane and with small amounts of other hydrocarbons. It is piped in large volumes to distances of hundreds of kilometers in steel pipes having large diameters and at pressures of about 60 Kg/cm^2. The cost of such transmission is often high. Gaseous fuels possess all the advantages of oil fuels except for ease of storage. The major limitation of using natural gas as fuel is that the power plant must be located near the natural gas field otherwise cost of transportation will be high.
- Cost of transportation of fuel is an important consideration in selecting the fuel for a thermal power plant (steam power plant).

Fuel Handling :

- Majority of the thermal (steam) power plants all over the world use coal as fuel. Therefore when dealing with the subject of fuel handling we restrict our discussion only to coal.
- In a thermal power station half of the total station operating cost is on account of coal and therefore problems of coal handling for a thermal power station require careful consideration.
- Requirements of a good coal handling plants are : it should be reliable, sound, simple requiring a minimum of operatives and minimum of maintenance. Besides the plant should be able to deliver the required quantity of coal at destination during peak periods. In essence, the function of coal handling system is to move coal from a receiving point to the firing equipment. The simplicity (or complexity) of the plant depends upon the way in which coal is received, orientation of the plant, desired capacity and flexibility of the arrangement. In order to satisfy a variety of conditions & meet several requirements an extensive array of mechanized handling devices may be combined in almost innumerable ways are usually available.
- While no coal handling system can be considered typical. Fig 4 shows various stages in coal handling. However it has to be remembered that it is not necessary that the flow chart may be followed as such in all the plants.

Depending upon the type of the plant intermediate steps may be eliminated or rearranged.

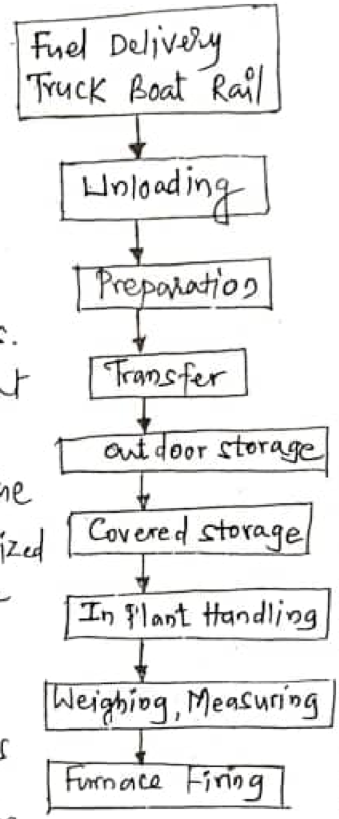

Fig4 Various steps in Coal handling

— Delivery of Coal: Coal may be delivered by sea or river, rail or road. Selection of proper method of coal supply from the coal mines to the power station depends upon the system capacity in tonnes per hour, location of the plant with respect to rail or water facilities available and location of available outside storage and overhead coal bunkers.

— Unloading: In unloading the choice of equipment will depend on how the coal is received.

— Preparation: Preparation coal before feeding to the combustion chamber becomes necessary only if unsized coal is brought to the site and sizing is derisable for purposes of storage and firing. A coal-preparation plant may include the following.
ⓐ Crushers ⓑ Sizers ⓒ Dryers ⓓ Magnetic Seperators

— Transfer: This means carrying coal from unloading point to the storage site from where it is discharged to the firing equipment. It may require one or more than one equipment depending on local conditions. Equipment used for this purpose may be one or more of the following.
i) Belt Conveyers (ii) Screw conveyers (iii) Bucket elevators
iv) Grab bucket conveyers (v) Skip hoists (vi) Flight Conveyers.

— Outdoor (dead) storage: Storage of coal is essential for two reasons: First is that it is an insurance against complete shut-down of a power plant which may arise from failure of normal coal delivery. (Eventualities like strikes in coal mines, failure of transport system, general shortage of coal etc. are taken care of by a proper storage system). Second reason for storage of coal is that advantage can be taken of seasonal market conditions. This means that when prices are low coal can be purchased/stored for future use. However, there are a number of factors such as risk of spontaneous combustion, possibility of deterioration of coal during storage, interest on account of blocked capital, cost of insurance, cost of handling coal because of storage etc. which storage of coal undesirable. Amount of coal to be stored depends on available space for storage, transporation facilities, amount of coal that will weather away & nearness of the power plant to the coal mines.

The usual practice is to store coal required for one month of operation of power station in case it is situated at a comparatively longer distance from the collieries whereas coal needed for about 15 days is stored in case of powerstations situated near to collieries. Storage of coal for longer periods is not advantageous because, as state above, it blocks the capital and results in deterioration of the quantity of coal. Coal received at the power station is stored in dead storage in the form of piles laid directly on the ground.

- Indoor (Live) storage : Such a storage constitutes coal requirements of the plant for a day. The live storage can be provided with bunkers and coal bins.
- Inplant handling : This refers to handling of coal between the final storage to the firing equipment. In case of simple stoker firing only chutes may be required to feed the coal from storage bunker to firing units. In addition to this gates and valves may be included in the system to control the flow according to load on the plant. The pulverised fuel firing system would require equipments such as chutes, pulverising mills, feeders, weighing and many others for inplant handling.
  (Equipments used for inplant handling are the same as used for coal transfer)
- Coal weighing : As stated earlier, cost of fuel is the major running cost of the plant. It is therefore very necessary to weigh coal at unloading point and also that used as feed to individual boilers. A correct measurement of coal enables one to have an idea of total quantity of coal delivered at the site and also whether or not proper quantity of has been burned as per load on the plant.
  (a) Weigh bridge (b) Belt scale (c) Automatic recording system.

* Fuel Combustion and combustion equipment :
Fuel is burned in a confined space called furnace. An efficient - Combustion of fuel is essential for economical working of powerplant. In case of firing unpulversed coal in combustion furnaces two general methods, namely hand firing and stoker (or mechanical) firing, are available. (A stoker is a fuel firing device which receives fuel by gravity, carries it into the furnace for combustion & after - combustion discharges the ash at the appropriate point). In the case of pulverised coal two delivery systems, namely unit system & central (or storage) system, are available.

Hand firing : This method of firing is simple, requiring no capital investment. This method can however be used only in small installations because uniformity of combustion is difficult to control in this type of firing. Further adjustments for the supply of air are to be made every time coal is fed to furnace.

Stoker firing : In this method of firing coal is carried into the furnace for Combustion and ash formed after Combustion is discharged at appropriate point. Stokers are designed for meeting specific requirements of fuels. It is possible to burn caking, non-caking or non-clinkering fuels. While some stokers can work with natural draught others need mechanical draught.

There are two main Classes of strokers. Thes are overfeed and underfeed. The two differ in the manner of feeding of Coal above or below the level at which primary air is admitted in the furnace. Thes are further classified as shown in fig 5.

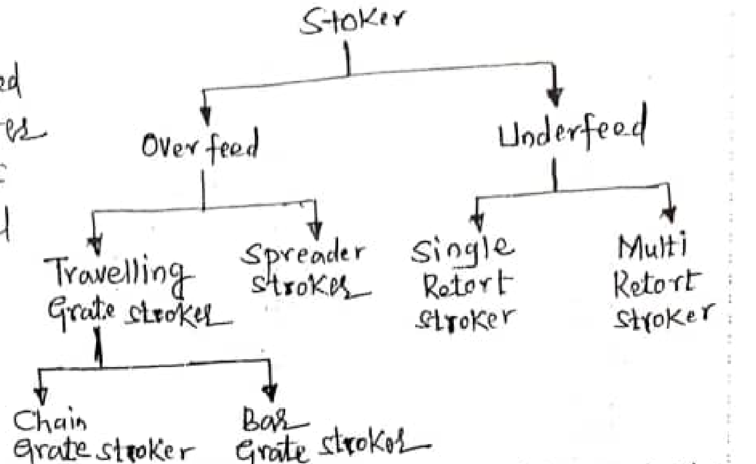

fig5. Classification of stokers

The distinction between overfeed and underfeed stokers will be clear from a reference to figures 6a and fig 6b below. In the case of overfeed stoker coal is fed on to the grate above the point of admission of air. In the case of an underfeed stoker fuel is fed from underneath the fire and works gradually upwards, primary air being supplied into the bed just below the level at which combustion takes place. Bituminous and semi-Bituminous Coals with small ash content and fusing temperature above 1300°C (caking or non-caking) can be burned very efficiently in these stokers.

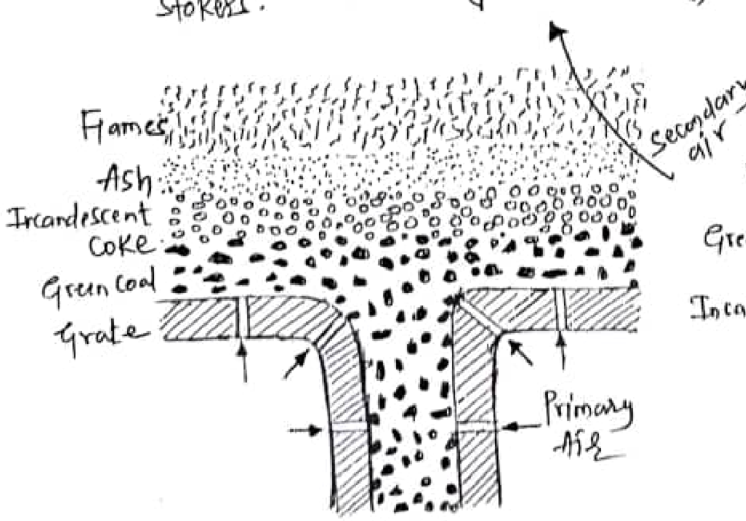

fig 6a
An over feed stoker

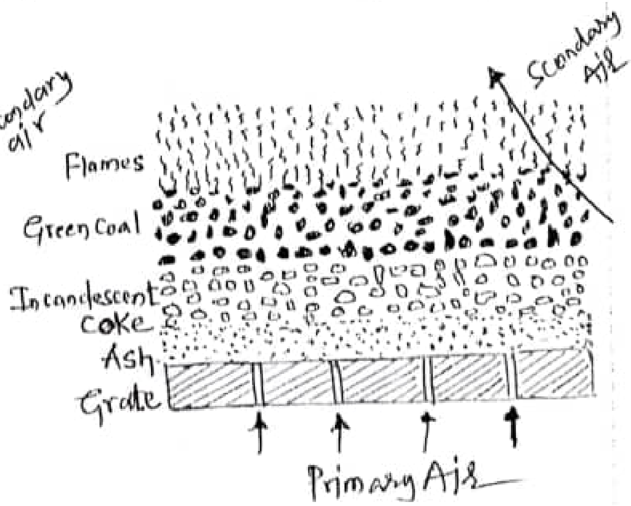

fig 6b
An underfeed stoker

Pulverised fuel system : Two delivery systems of pulverised fuel are in common use. These are – the unit system and central (or bin) system. In the unit system each furnace is fired by one (or more) unit-pulverizer connected to its burners while in the central system fuel is pulverized in a central plant and then distributed to each furnace with the help of high pressure air current. Present day practice favours the unit system due to facility in control. In each type the fuel processing equipment consists of crushers, magnetic separators, driers, pulverising mills, storage bins, conveyers and feeders.

Coal purverising Mills : Essential requirements of such mills are drying of coal, grinding, separation of ~~practi~~ particles of desired size, forming proper fuel-air ratio and suitable controls for all these operations.

* Coal Burners : Pulverised fuel Burners. In its simplest form a burner incorporates an arrangement for supplying correct amount of fuel and air to the furnace. (Depending upon the type of fuel handled by a burner it may be known as a liquid fuel burner, gas fuel burner, pulverised fuel burner etc).

Pulverised fuel burners may be classified as :

i) Long Flame Burners ii) Turbulent Burners
ii) Tangential Burners iv) Cyclone Burners.

* Fluidized-Bed Combustion :

Direct combustion of coal is best acomplished by fluidized bed combustion (CFBC). If compressed gas is passed upward through a bed of inert particles at a sufficient velocity to overcome gravity, each particle will float on the gas stream in a boiling turbulent mass. This is known as fluidized Bed. Coal particles are added to the inert mass and may constitute only 10% of the mass and thus cannot adhere to each other or agglomerate. Instead of inert particles such as ash and sand, lime stone or dolomite is ~~wit~~ widely used in proper proportional to combine with sulphur in coal and produce solid ~~surface~~ sulphate particles. The production of nitrogen oxides $(NO)_x$ is also reduced greately at lower combustion temperatures. Thus it has advantages : direct removal of sulphur during combustion ; low NO_x emission, ability to burn a variety of fuels, and smaller size.

* Combustion Control :

Automatic Combustion control. When the load on a generator changes there is a corresponding change in demand for steam. Automatic

Control regulates ~~at~~ automatically changes in demand of steam & also effects quick and suitable changes in other variables so as to maintain constant steam pressure and proper combustion conditions.
It is obvious that an automatic combustion control system has to maintain constant steam pressure under all load conditions. The parameters to be controlled with variations in load are steam, water, fuel and air etc. (An automatic control saves manual labour)

- In practice combustion control devices based upon changes in steam pressure are most popular. (Any one or a combination of fluctuation in steam pressure, rate of steam flow, furnace draught can be used).

* Ash handling and Dust collection :

In a large power station ash accounts for 10 to 20% of the coal burnt. For a large rating of the power station a huge quantity of ash is therefore is to be disposed of. Handling of ash is a problem because ash coming out of the furnace is (i) too hot (ii) dusty (therefore irritating to handle) and (iii) it produces poisonous gases and corrosive acids when ~~are~~ mixed with water.

- Ash handling system : There are four groups into which modern ash handling systems may be divided. These are
  (i) Mechanical handling system (ii) Hydraulic system.
  (iii) Pneumatic system (iv) Steam jet system.
- Dust collection : Dust may be defined as the solid matter in fluegases which is more than 0.001 mm and less than 0.1 mm in diameter.
Quantity of dust in fluegases largely depends upon the method of fuel firing. Dust nuisance is greatest with pulverised fuel and spreader stoker firing systems and is much less with underfeed stoker systems.
To give an idea of the problem a 100 MW capacity power station using pulverised coal as fuel will discharge as much as ~~fuel will~~ 150 tonnes of ash per day with the exhaust gases if due care is not taken to remove the dust particles from the exhaust gases.
- Major emissions from thermal power stations are fly-ash, carbon ash (known as cinder), smoke, dust and irritating vapours like CO, SO_2 & nitrogen oxides. These emissions are objectionable if the content exceeds a particular limit.
- Indian coals contain a very high percentage (around 40%) of ash. With pulverised form of coal firing upto 80% of ash in the coal may be carried ~~out~~ with exhaust gases in a very fine form. Another difficulty with Indian coals is the higher percentage of sulphur. Sulphur emitted to the atmosphere in the form of sulphur dioxide is highly objectionable on account of its bad effects on human beings.

- In view of above cleaning of flue gases for power stations using Indian coal as fuel is very necessary. However cleaning of gases is a difficult problem because of (a) large percentage of silica in the ash and (b) fineness of typical fly-ash.
- Gas cleaning devices make use of certain physical/electrical properties of the particulate matter of the gas stream. Basically gas cleaning devices (or dust collectors) may be classified into mechanical & electrical (electrostatic precipitators). Mechanical dust collectors have efficiency increasing with load while the efficiency of electrostatic precipitators falls as load increases. A combination of the two collectors gives a constant efficiency characteristics and is often used. The mechanical unit serves to remove heavier dust particles and the electrostatic controller eliminates finer particles.

* Draught Systems :
- The purpose of draught is to supply an adequate amount of air for combustion and bring it into intimate contact with the fuel. Problems associated with draught includes introduction of proper quantity of air at the proper place and removal of products of combustion.
- Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure. Draught is achieved by small pressure difference which causes the flow of air or gas is to take place. It is measured in millimeters (mm) of water. (Accordingly draught can be produced by ~~means~~ use of chimney, fan, steam or air jet or a combination of these.) [When the draught is with the help of chimney only, it is known as natural draught] and ~~th~~ (when the draught is produced by any other means except chimney it is known as mechanical or artificial draught.) We may therefore, say that when the draught is produced by action of chimney alone it is called natural draught remove this (no fan is needed in this case). (When the draught is produced by drawing out gases from the chimney with the help of a fan placed at the chimney base it is called an Induced draught). (Similarly when the draught is produced by forcing air through the fuel bed with the help of a fan it is called a Forced draught).
Artifical draught may be classified into mechanical draught & steam jet draught. (Steam jet draught is preferred in small installations & locomotives while mechanical draught is preferred for central power stations).

* Feed Water :

(Natural water cannot be used as such for steam generation as it contains solid, liquid and gaseous impurities, which damage the blades of turbine.) This water as such cannot, therefore, be used for generation of steam in the boilers. (Impurities in raw water have to be removed before it use in boilers.) Even though main Condensate returns to the boiler as feed water make-up water is still required to replace the loss of water due to blow-down, leakage etc. In this cycle. Notwithstanding the fact that the amount of make-up water required is only about 1% the total make-up water required for 100 MW plant will be of the order of 25-30 tonnes per hour. As such, in general, it becomes necessary to have a seperate water softening plant.

Different impurities in natural (raw) water as follows :

(i). Undissolved and suspended solid materials (turbidity & sediment which includes Coarse particles like mud, sediment, sand etc. & sodium & potassium salts etc. Sometimes some iron, manganese or silica are also present) (ii) Dissolved salts and minerals. (These include carbonates, bicarbonates, sulphates & chlorides of calcium & magnesium)
(iii) Dissolved gases such as carbon dioxide and oxygen
(iv) other materials (such as oil, acid) either in mixed or unmixed forms.

- Operational troubles are caused due to impurities in feed water : These are (i) Scale formation (ii) Corrosion (iii) Priming, foaming & carry over (iv) Caustic embrittlement.
- Different methods of feed water treatment : The basic purpose of water treatment is to remove suspended solids, dissolved solids & dissolved gases from water before it is supplied to boiler. These are three main groups of water treatment namely.
(i) Mechanical treatment (ii) Thermal treatment (iii) Chemical treatment.
- Evaporators : These are used for supplying pure water as make-up feed water in the boilers. In an evaporator raw water is evaporated by using extracted steam. It is then condensed to give distilled & pure feed water. There are two main classes of evaporators. These are film type & submerged type.

Feed Water heaters : These heaters are used to heat feed water before it is supplied to the boiler. There are two types of heaters, namely Contact or open & surface or closed heaters.

* Steam Power plant controls & Plant auxiliaries :

- A number of controls at the boiler, turbine and generator unit are provided in a steam station in order to maintain the best conditions at different loads.
- We have already considered automatic combustion control for maintaining the best boiler efficiency and seen how this control keeps fuel/air ratio constant while the load changes.
- Turbine governing is effected in either of two ways. In the case of small turbine it is throttling at a single inlet valve. For a large turbine a number of nozzles at the steam inlet are provided; these nozzles gradually open one after the other as the load on the turbine is increased. Maintaining proper vacuum in the condenser, enough circulating water, a number of pumps, oil pressure for control of circuits, steam bleeding if any and the heater & feed-water control are other equipments of the turbine.
- At the generator an increase in load will result in a reduction in frequency for an isolated generator. However, if the generator is connected to infinite busbars (i.e large number of generators working in parallel) the load taken by the generator can be adjusted by adjusting the speed of the turbine, for in that case the frequency remains constant and the change of excitation changes the power factor of the generator.
- In general centralised control is adopted for modern steam stations, the boiler and turbine control being at one place in the turbine room and the generator and feeder controls in the control room; in some cases all controls are centralized at one place in the control room.
- Most of the controls are automatic. A number of annunciators & indicating instruments help in controlling the operation of the steam station very effectively.

Plant auxiliaries

- Boiler make-up water treatment plant and storage : since there is a continuous withdrawal of steam and continuous return of condensate to the boiler, losses due to blow down and leakage have to be made up to maintain a desired water level in the boiler steam drum. For this continuous make-up water is added to the boiler system. Hardness of water is removed by a water demineralising treatment plant (DM), as hardness in the make-up water to the boiler will form deposits on the tube water surfaces which would lead to overheating & failure of tubes. (A storage tank is installed from which DM water is continuously withdrawn for boiler make-up.) The storage tank for DM water is made from materials not affected by corrosive water. The piping & valves are generally of stainless steel.

Fuel preparation system : In coal fired power stations, the raw feed coal from the coal storage is first crushed into small pieces and then conveyed to the coal feed hoppers at the boilers. The coal is next pulverised into a very fine powder. The pulverisers may be ball mills, rotating drum grinders or other type of grinders.

Barring gear : (or turning gear) is the mechanism provided to rotate the turbine generator shaft at a very low speed after unit stoppages.

~~oil system~~ : Once the unit is tripped (i.e the steam inlet valve is closed), the turbine coasts down towards standstill. When it stops completely, there is a tendency for the turbine shaft to deflect or bend if allowed to remain in one position too long. This is because the heat inside the turbine casing tends to concentrate in the top half of the casing, making the top half portion of the shaft hotter than bottom half. The shaft therefore could warp or bend by millionths of inches.

Oil system : An auxiliary oil system pump is used to supply oil at the start-up of the steam turbine generator. It supplies the hydraulic oil system required for steam turbine's main inlet steam stop valve, the governing control valves, the bearing and seal oil systems, the relevant hydraulic relays and other mechanisms.

Generator cooling : While small generator may be cooled by air drawn through filters at the inlet, larger units generally require special cooling arrangements. Hydrogen gas cooling, in an oil-sealed cooling, is used because it has the highest known heat transfer coefficient of any gas and for its low viscosity which reduces windage losses.

Generator high voltage system : The generator voltage for modern utility connected generators ranges from 11KV in smaller units to 30KV in larger units. The generator high-voltage leads are normally large aluminium channels are connected to step-up transformers for connecting to a high-voltage electrical substation (usually in the range of 115KV to 765KV) for further transmission by the local power grid.

Monitoring & alarm system : The plant is provided with monitors & alarm systems that alert the plant operators when certain operating parameters are seriously deviating from their normal range.

Battery-supplied emergency lighting & communication : A central battery system consisting of lead acid cells units is provided to supply emergency electric power, when needed, to essential items, such as the power plant's control systems, communication systems, generator hydrogen seal system, turbine lube oil pumps, & emergency lighting. This is essential for safe, damage free shutdown of the units in an emergency situation.

Circulating water system : To dissipate thermal load of main turbine exhaust steam condensate from gland steam condenser, & condensate from low pressure heater by providing a continuous supply of cooling water to the main condenser thereby leading to condensation.

8, ✱ 51, 53, 55, 64, 69. ✱ 7, 8, 12, 15, 17, 19, 24, 27, 32, 36, 45, 46, 57, 60, 64, 68, →

Diesel Power Plant

- In diesel power plant a diesel engine is used as a prime mover for the power generation. The diesel engines uses a diesel as fuel. The heat energy obtained by the ~~Combustion~~ combustion of the diesel is converted into mechanical energy. An alternator or a d.c. generator mechanically coupled to the diesel engine which converts the mechanical energy into electrical energy.
- These~~fore~~ diesel plants are more efficient than any other heat engine of comparable size. (These plants are cheap by way of initial cost, can be started and stopped quickly and can burn a wide range of fuels.) A diesel plant does not require any warming period; It need not be kept running for a long time before picking up load. As a result there are no standby losses. Another advantage of such a plant is that it does not need large amount of water for cooling. A diesel station can be commissioned in a much shorter time compared with a hydro, steam or nuclear power station.

Although steam power stations & hydro-electric plants are invariably used to generate bulk power at cheaper cost, yet diesel power stations are finding favour at places where demand of power is less, sufficient quantity of coal and water is not available & the transportation facilities are inadequate. These plants are also used as standby sets for continuity of supply to important points such as hospitals, radio stations, cinema houses & telephone exchanges.

* Merits of diesel power plants

Diesel power plants offer several advantages as follows.

(i) The capital cost per kW is low.
(ii) The design and installation are simple & cheap.
(iii) It occupies less space as the number and size of the auxiliaries is small.
(iv) These can be easily procured, installed & commissioned in less time.
(v) Starting time & stopping time are very less. Thus can be put into service and taken out quickly.
(vi) These have the good efficiency (approximately 40-45%), which is higher than thermal power plants.
(vii) Small diesel generators can be portable & can be put any near any load requirement. However a big size diesel power plant can be located near load centres as it requires less space.
(viii) These power plants are free from ash & require less water for cooling system.
(ix) The operation is simpler, & ~~req~~ lesser operating & supervising staff is needed than a thermal power plant.

* Demerits of diesel power plant:

The diesel power plants have several disadvantages as well. They are

(i) The operating cost of it is very high as diesel is more costly than coal.

(ii) The size of diesel unit is limited & very large capacity is not possible with these prime movers.

(iii) Their repair and maintenance costs are high.

(iv) The useful life is very less (approximately 5-10 years)

(v) They have limited overload capacity.

(vi) The noise & air pollution is more.

* Selection of site for diesel power station:

The following factors are to be considered while selecting site for diesel power station.

(i) Distance from Load Centre

(ii) Availability of land and water

(iii) Foundations

(iv) Transport of fuel

(v) Local conditions

(vi) Neighbourhood Noise & Nuisance.

* Elements of diesel power plant

The essential components of a Diesel electric plant are:

(i) Engine (ii) Engine fuel system (iii) Engine air intake system

(iv) Engine exhaust system (v) Engine cooling system.

(vi) Engine lubricating system (vii) Engine starting system

(i) Engine: This is the main component of the plant which develops power. Generally engine is coupled directly to the generator.

(ii) Engine fuel system: This includes the fuel storage tanks, Fuel transfer pumps, strainers, heaters & connecting pipe work. Fuel transfer pumps are required to transfer fuel from delivery point to storage tanks and from storage tanks to engine. Strainers are needed to ensure clean fuel. Heaters for oil may be required especially during winter.

(iii) Engine air intake system: This includes air filters, ducts & supercharger (an integral part of engine). The purpose of air filters is to remove dust from the air to be supplied to the engine.

The system supplies the required quantity of air for combustion. The supercharger increases the pressure of air supplied to the engine so that it could develop an increased power output. Super-chargers are generally driven by the engines.

(iv) <u>Engine Exhaust system</u> : This includes silencers & connecting ducts. As the temperature of exhaust gases is sufficiently high, heat of these gases is utilised in heating oil or air supplied to the engine. The silencer reduces the noise level.

(v) <u>Engine Cooling system</u> : This includes coolant pumps, cooling towers or spray ponds, water treatment or filtration plant & connecting pipe work. The purpose of cooling system is to carry heat from engine cylinder to keep the temperature of cylinder within safe limits. The pump circulates water through cylinder & head jackets to carry away heat. Thus the simplest cooling system would need only a water source, a pump and a place for disposal of hot water. Usually, however, the same water is recirculated by cooling it in devices such as radiators, evaporative coolers, cooling towers, spray ponds etc.

(vi) <u>Engine Lubrication System</u> : This includes lubricating oil pumps, oil tanks, coolers, purifiers and connecting pipe work. The function of the lubrication system is to reduce the friction of moving parts & reduce the wear and tear of the engine parts.

(vii) <u>Engine starting system</u> : This includes storage battery, compressed air tanks, self starter etc. The function of the starting system is to start the engine from cold by supplying compressed air. The system enables the engine to rotate initially while starting until the firing starts and the units runs on its own power.

(viii) <u>Alternator</u> : The alternators used in diesel power plants are of rotating field, salient pole construction, speed ranging from 214 to 1000 rpm (Poles 28 to 6) & capacities ranging from 25 to 5000 kVA at 0.8 pf lagging. Their output voltages are 440V in case of small machines & as high as 2200V in case of large machines. Voltage Regulation is about 30 %.

Governers : Modern diesel engines are equipped with either non-isochronous or isochronous governers. In non-isochronous governers the flow is regulated from flyweights or it may be a relay type employing a hydraulic or electric system. Isochronous governers are relay type and usually supplied for the diesel engine having parallel operation. All diesel engines should be supplied with emergency over speed governers to stop the units when the speed exceeds by 10%.

Applications of Diesel power plants :

(i) Emergency plant : It is used as emergency power plant in most of the industries.
(ii) They are used for starting auxiliaries in steam power stations.
(iii) Mobile plants : These are used as a mobile power plants for temperory & emergency purposes.
(iv) These are used as peak load plants for quick starting & loading.
(v) These are used as stand by plants.
(vi) Used in remote locations where supply from grid is not available.

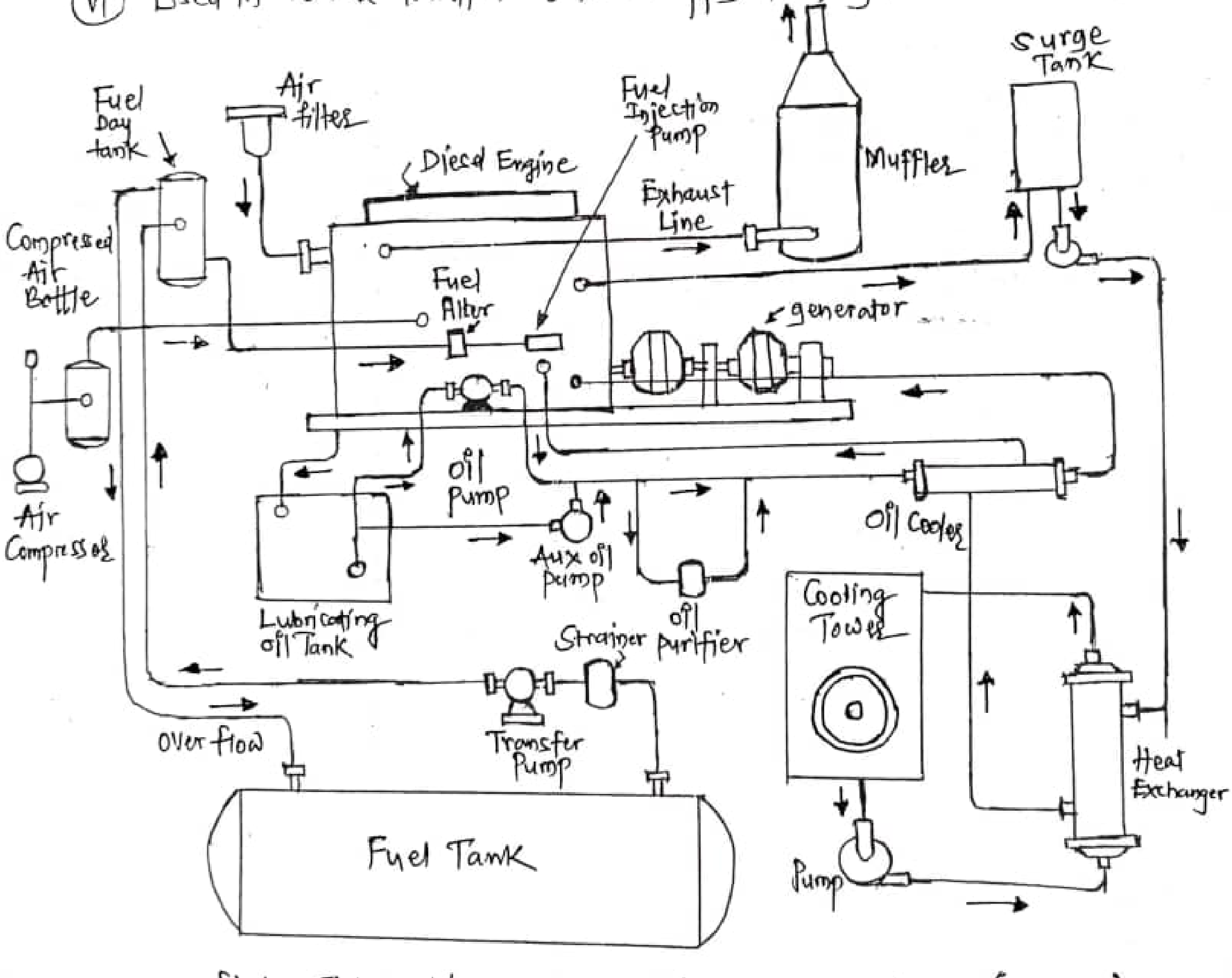

fig 1. Schematic diagram of Diesel power plant (Layout)

Gas Turbine Power Plant

- A generating station which employs gas turbine as the prime mover for the generation of electrical energy is known as a gas turbine power plant.
- In a gas turbine power plant air is used as the working fluid. The air is compressed by the compressor and is led to the combustion chamber where heat is added to air, thus raising its temperature. Heat is added to the compressed air either by burning fuel in the chamber or by the use of air heaters. The hot and high pressure air from the combustion chamber is then passed to the gas turbine where it expands and does the mechanical work. The gas turbine drives the alternator which converts mechanical energy into electrical energy. It may be mentioned here that compressor, gas turbine & the alternator are mounted on the same shaft so that a part of mechanical power of the turbine can be utilised for the operation of the compressor. Gas turbine power plants are being used as standby plants for hydro-electric stations, as a starting plant for driving auxiliaries in power plants etc.
- Gas turbine (GT) based technology is of great interest to the developing countries because it is the most efficient technology for converting fossil fuels into electricity and because of ongoing research and development to make it even more efficient. In addition gas turbine generates relatively low level of greenhouse gases (GHG), such as carbon dioxide. Finally, GT based technology has the flexibility to deal with the situations where natural gas is not readily available (a situation that frequently occur in developing countries) because it can handle a wide variety of low calorific value & ~~Contained~~ - Contaminated fuels, the latter requiring a lot of care for their successful operation.

* Merits & Demerits of Gas turbine plant :

* (I) Merits of gas turbine plant :

(i) Gas turbine system is compact & required less space compared to steam power plant of same capacity
(ii) It requires fewer auxiliaries & installation takes less time
(iii) There is no condenser maintenance.
(iv) It requires a simple lubricating system, light foundation.
(v) It can be easily controlled.
(vi) It can be quickly started & as compared to steam power plant.
(vii) The fuel consumption is low during the starting & shutting down.

(viii) There is clean exhaust & there is no stack required.
(ix) Due to fewer auxiliaries, the required personnel to run the plant are also less.
(x) In the case of no run plant, personnel required are almost nil.
(xi) Virtually, there is no water requirement.
(xii) Gas-turbine plants have low weight power ratio.
(xiii) It is also economical to operate below a given power factor & thus saving of cost.
(xiv) The capital cost is comparatively smaller than that of steam power plant.

* Demerits of Gas turbine power plant :

(i) There is a problem for quick starting the unit. Because the external source power is required to start turbine & compressor has to be operated before the unit starts.
(ii) Since lot of the power developed by the turbine is used in driving the compressor, the net output is low.
(iii) The overall efficiency of gas turbine plant is low (about 20%) because exhaust gases from the turbine contain sufficient heat.
(iv) The temperature of combustion chamber is quite high (2000° F) so that the life is comparatively reduced.

* Selection of site :

Following are the factors to be considered for selection of site for Gas turbine power plant.
(i) Distance from load centre
(ii) Availability of land at reasonable rate
(iii) Availability of fuel at reasonable rate.
(iv) Availability of transportation facilities.
(v) Distance from populated areas
(vi) Type of land (land should be of high bearing capacity)

* Fuels for Gas turbines :

A wide variety of fuels from solid to gaseous can be used in gas turbine plants. The ideal fuel is of course natural gas but ~~is~~ this is not always available. Natural gas is obtained from wells in oil fields. It is generally used for auxiliary power production within the oil fields. Blast furnace & producer gas can also be used for these plants.

Liquid fuels of petroleum origin such as distillate oils or residual fuels (including oils, furnace oils, boiler fuel oils) are most commonly used for such plants. When using such fuels one has to be very careful that the fuel used possesses proper volatility, viscosity & calorific value. Also the fuel should be free from any content of moisture & suspended impurities that may clog the small passages of the nozzles & damage valves & plungers of the fuel pumps. Minerals like sodium, vanadium & calcium prove very harmful for the turbine blading as they build up deposits or corrode the blades. Distillate fuels burn with more ease than do residual fuels. Therefore when starting the unit from cold initially in distillate fuels are fed into the combustor after which residual fuels may be fed. In cold climate it may be necessary to preheat residual fuels. Use of solid fuels (for example pulverised coal) in gas turbines presents a number of difficulties. In view of the difficulties involved even though the use of coal as fuel for closed cycle plant is universally accepted, its use in open cycle plant is not yet developed.

One further advantage of gas turbines is their fuel flexibility. They can be adopted to use almost any flammable gas or light distillate petroleum products such as gasoline (petrol), diesel & kerosene (paraffin) which happen to be available locally, though natural gas is most commonly used fuel. Crude and other heavy oils and can also be used to fuel gas turbines if they are first heated to reduce their visocity to a level suitable for burning in the turbine combustion chambers.

Elements of simple gas turbine power plant :

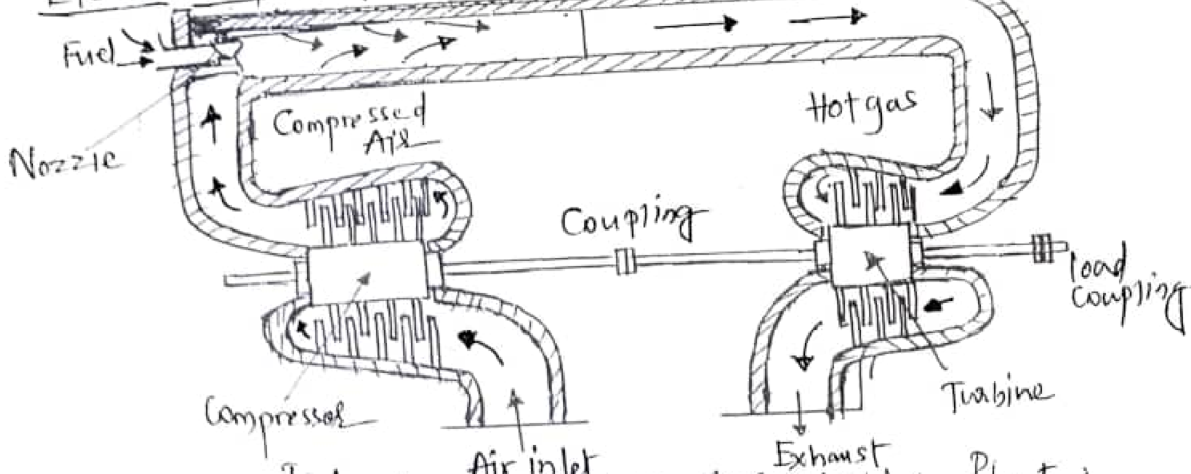

Fig 1. Arrangement of simple gas turbine Plant :

A simple gas turbine plant consists of a compressor, combustion chamber or combustor & turbine. Besides these main components there may be auxiliaries such as starting device, fuel system, the duct system, auxiliary lubricating system etc. A simple gas turbine plant is shown in fig1.

Compressor: The compressor used in the plant is generally of rotary type. The air at atmospheric pressure is drawn by the compressor via the filter which removes the dust from air. The rotary blades to raise its pressure. The air at high pressure is available at the output of the compressor.

Combustion chamber: The air at high pressure from the compressor is supplied to the combustion chamber via the generator. In the combustion chamber heat is added to the air by burning oil. The oil injected through the burner into the chamber at high pressure to ensure atomisation of oil & its proper mixing with air ~~air~~ results in proper burning of mixture & chamber attains a very high temperature (about 3000°F). The combustion gases are suitably cooled to 1300°F to 1500°F & then delivered to the gas turbine.

Gas turbine: The products of combustion comprising of a mixture of gases at high temperature & pressure are passed to the gas turbine. These gases while passing over the turbine blades expand and causing the turbine blades to rotate. The temperature of the exhaust gases from the turbine is about 900°F.

Alternator: The gas turbine is coupled to the alternator. It converts mechanical (rotary) energy into electrical energy. The output from the alternator is given to the bus-bars through transformer, circuit breaker & isolators.

Starting Motor: Before starting the turbine, compressor has to be started. For this purpose an electric motor is mounted on the same shaft of the turbine. The motor is energized from batteries. Once the unit starts, a part of mechanical power of the turbine drives the compressor & there is no need of motor then.

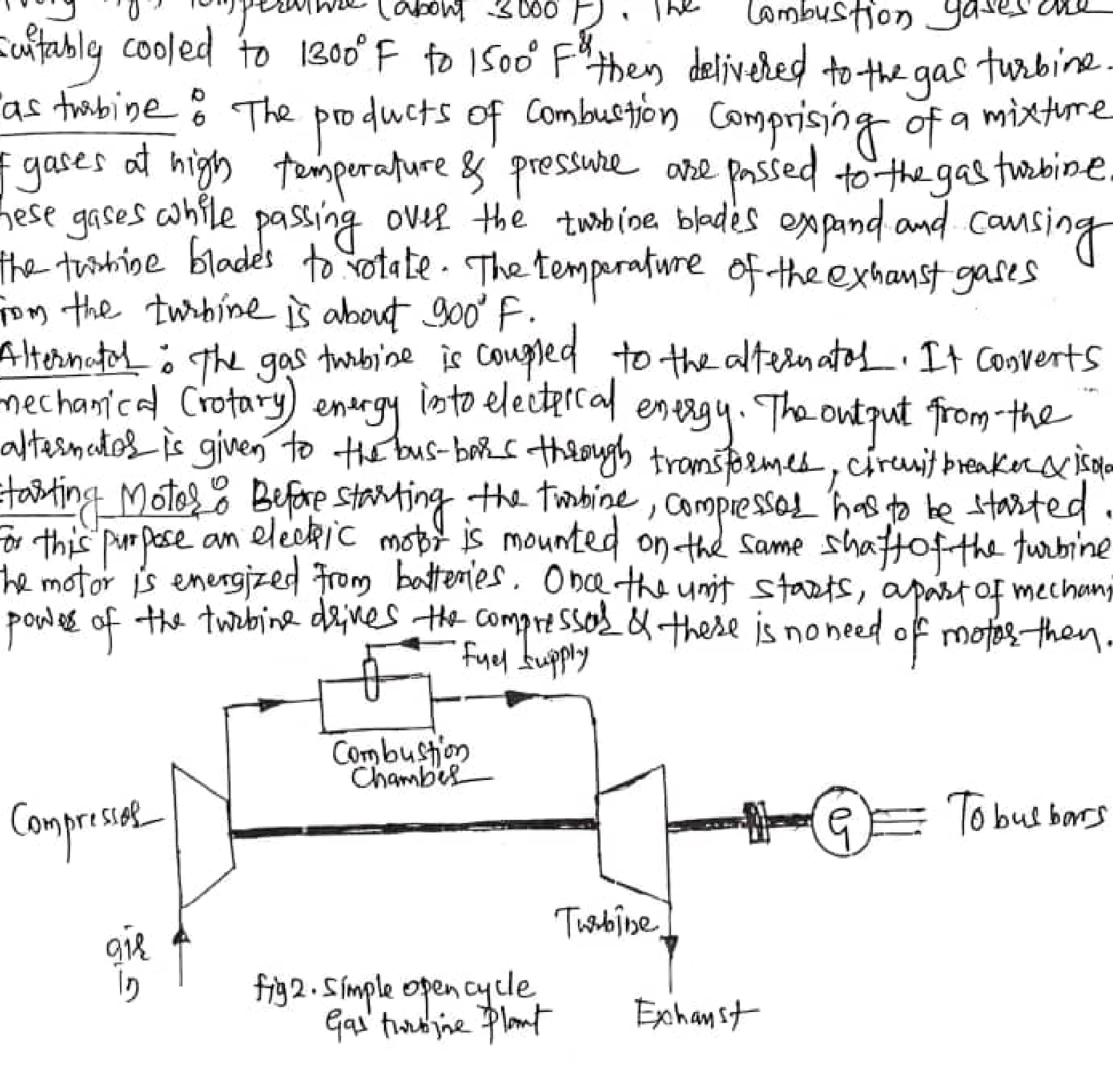

fig2. Simple open cycle Gas turbine Plant

* Methods of Improving thermal efficiency of a simple gas power plant :

The efficiency of simple gas turbine is very low. There are three methods to increase the thermal efficiency of the cycle, where are :- regeneration, reheating and intercooling.

Regeneration : Recovering waste heat from the high-temperature exhaust gases of a gas turbine is a means of improving the cycle efficiency. It is similar to the air preheater in the case of thermal power plants. The device used for extracting the heat from the heated gas is called regenerator or heat exchanger. These are either tubular or rotary plate type in construction. fig 3a. below shows a line diagram of gas turbine with regenerator

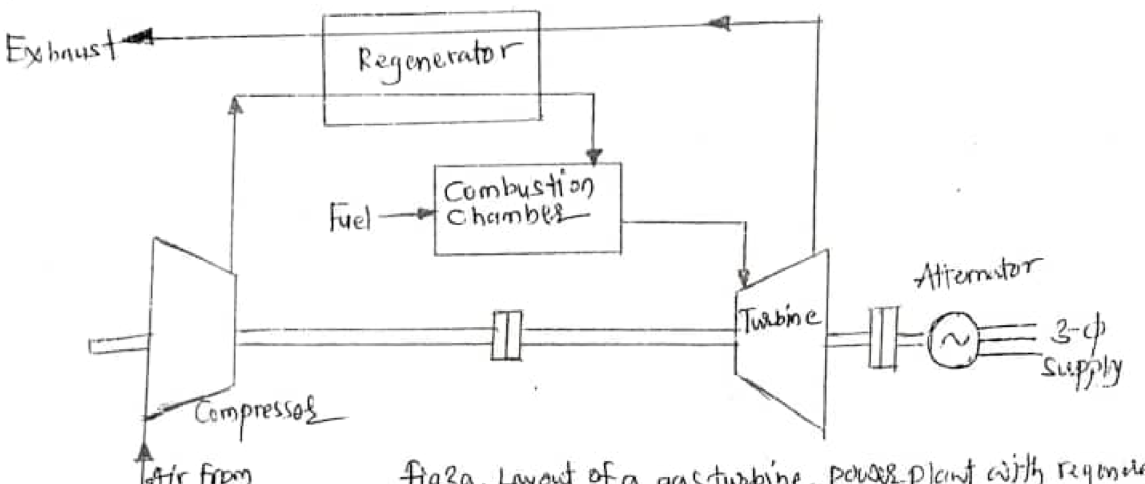

fig 3a. Layout of a gas turbine power plant with regenerator

It should be noted that with the addition of regenerator in the circuit there is no change in compressor & turbine work but the quantity of fuel supplied is substantially reduced (i.e there is gain in heat recovery) as the temperature of the air entering the combustion chamber is increased. In order to improve heat transfer from the regenerator there are two choices : one is to increase the surface area & other is to increase the turbulence of flow. However the first choice involves higher initial cost while the second results in an increased pressure drop. As such the design of regenerator is a compromise between the gain in heat recovery on the one hand & higher initial & operating cost on the other.

Reheating : Partially expanded high-temperature gas in turbine can be reheated so that it can be expanded further to produce additional work. There may be several stages of heating. If only one turbine is there, then there will be no use of reheating. In two-stage turbine, one reheater can be used, as shown in fig 3b. It improves the performance of the gas turbine, by improving the output from the turbine due to multiple heating. Reheater may in fact be taken as an additional combustor.

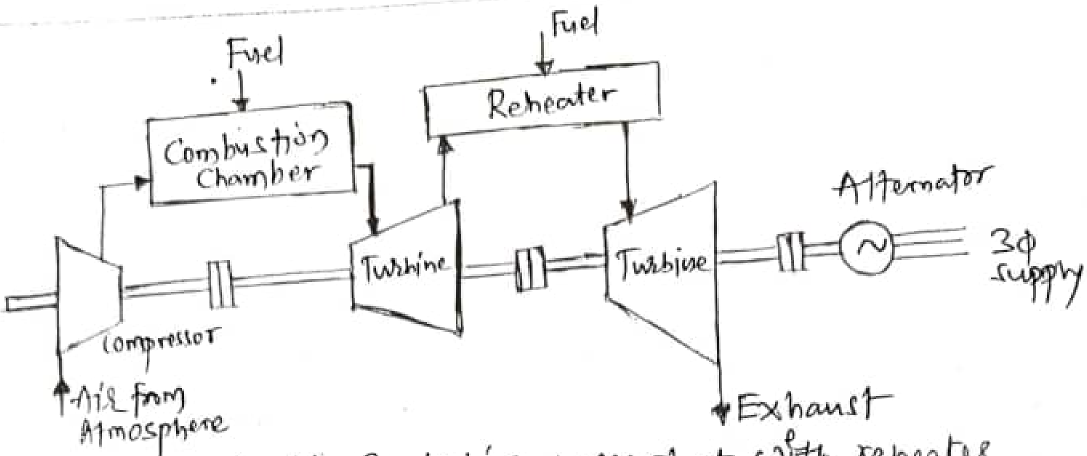

fig 3b. Gas turbine power plant with reheater

Intercooling : Compressor Consumes very high energy & therefore two compressors are used with intercooling, which acts as a heat exchanger, as shown in fig 3C. below. The power required to run the Compressor could be reduced because reduction in the volume of air-cooled. The number of stages of compressors are decided based on the cost & energy saving. Intercooling results in the enhancement of thermal efficiency, air rate and work ratio. Therefore overall size of the power plant is reduced for same capacity. Normally, air or water is used to cool the compressor. Intercooling means cooling the air after it has been partially compressed.

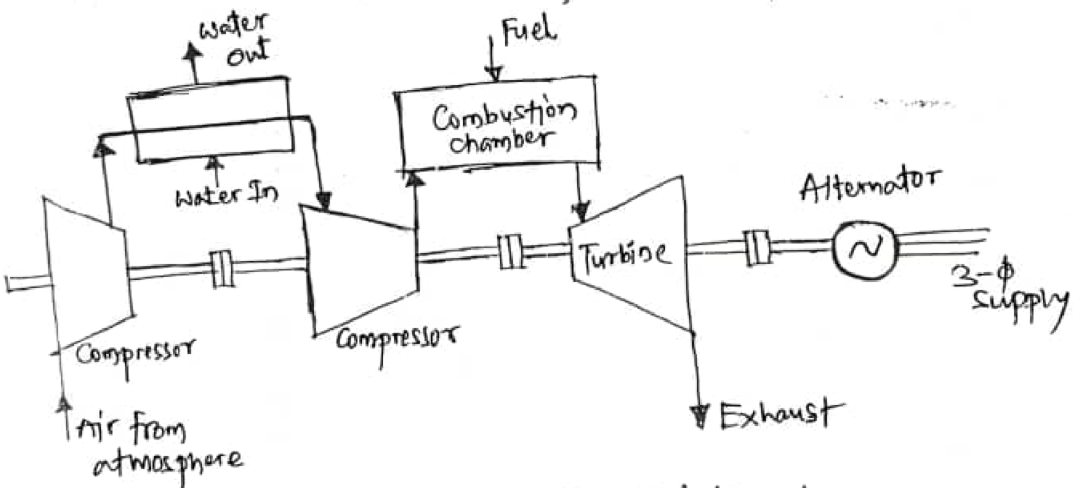

fig 3C. Gas turbine power plant with intercooler.

— We may conclude that our discussion by saying that the thermal efficiency of a simple gas turbine plant can be increased by using one or more of the methods described above.

These are based on,

ⓐ Reducing the work required to run the compressor (intercooling).

ⓑ Reducing the heat (fuel) supplied to the combustor (regeneration, reheating)

In an actual power plant intercooling, regeneration & reheating may all be used to increase the overall thermal efficiency of the plant & specific power output. Fig 3d. shows such an arrangement.

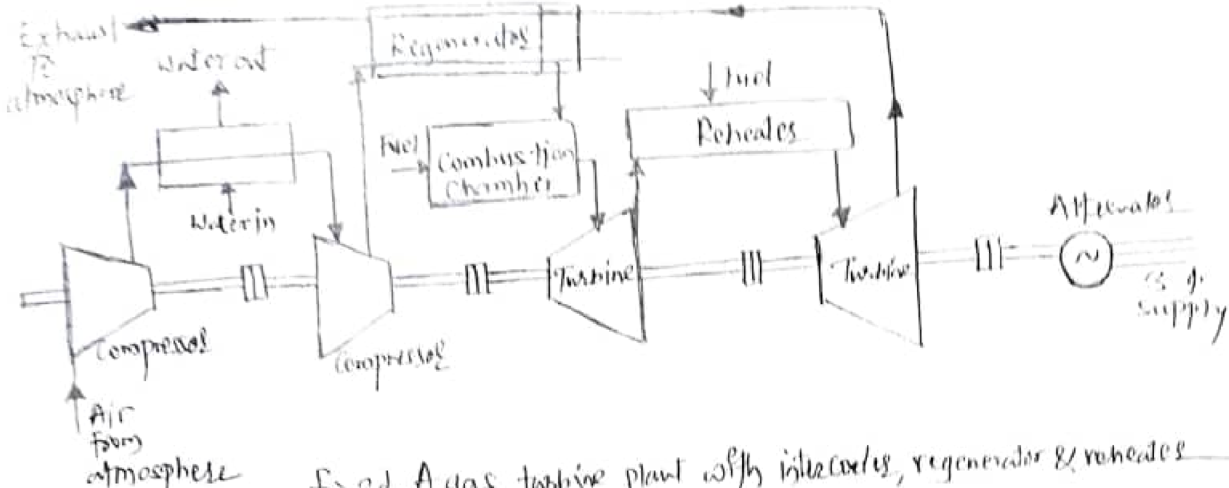

fig 3d. A gas turbine plant with intercooler, regenerator & reheater

* Closed cycle gas turbine power plant :

In closed cycle gas turbine as shown in fig 4 below, the heat to the working ~~fluid~~ medium (air or any suitable gas) is given without directly burning the fuel in the medium & the same working fluid is used again and again in the cycle. In this working fluid is compressed in the compressor and is fed into the heater where it is heated up to the temperature of turbine inlet. This fluid is then expanded in the turbine & the exhaust is cooled to the original temperature in the recooler (pre-cooler). It then enters the compressor to begin the next cycle. The heater burns any suitable fuel & provides the heat for heating the working medium. In fact the combustor is similar to an ordinary boiler furnace working at the atmospheric pressure and discharging the gaseous products to the atmosphere. The precooler (recooler) corresponds to the condenser of a steam plant. The air heater corresponds to the water heater of the steam plant. Closed cycle gas turbine plants are not yet used for the generation of electricity due to large size of required heat exchangers.

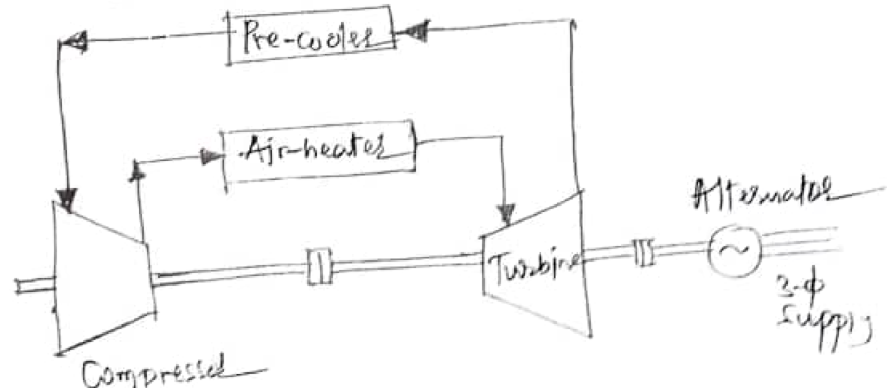

fig 4. Closed cycle gas turbine power plant.

* Comparison of gas turbine power plant with steam & diesel power plants.

SN	Item	Steam Power Plant	Diesel Power Plant	Gas turbine Power Plant
1.	Site	Such Plants are located at a place where ample supply of water & coal is available, transport facilities are adequate	such plants can be located at any place because they require less space & small quantity of water	
2.	Initial cost	Initial cost is lower than that of hydro electric & nuclear power plants	Initial cost less as compared to other power plants	
3.	Running cost	Higher than that of ~~Diesel & gas turbine Plants~~ hydro & nuclear plants because of requirement of huge amount of coal	Highest among all plants because of high price of diesel.	
4.	Limits of source of power	Coal is the source of power which has limited reserves all over the world	Diesel is the source of power which is not available in huge quantities due to limited reserves.	
5.	Cost of fuel transportation	Maximum because huge amount of coal is transported to the plant site	Higher than hydro & nuclear power plant	
6.	Cleanliness & simplicity	Least clean as atmosphere is polluted due to smoke	More clean than steam & gas power plants.	
7.	overall efficiency	Least efficient. overall efficiency is about 25%.	More efficient than steam power plant. Efficiency is about 35%.	3/13 7, 12, 24, 27, 28, 38, 43, 45, 64, 66, 68,
8.	starting	Requires a lot of time for starting	can be started quickly	3d3 2, 6, 7, 12, 17, 21, 24, 28, 35,
9.	Space Required	These plant requires sufficient space because of boilers & auxiliaries	Require less space	38, 43, 45, 63, 64, 68, 69,
10.	Maintenance cost	Quite high as skilled operating staff are required	Less	*28/3/17 → 6, 7, 9, 14, 16, 17, 19, 20, 21, 23, 24, 27, 28, 33, 35, 36,
11.	Transmission & Distribution cost	Quite low as these are generally located near load centres	Least as they are generally located at the centre of gravity of the load.	39, 43, 44, 45, 46, 50, 58, 60, 61, 62, 63, 64, 65, 66, 70. = 39
12.	Standby losses	Minimum as the boiler remains in operation even when the turbine is not working	Less standby losses.	*22/3/17 - 3, 4, 12, 17, 20, 21, 25, 26, 27, 28, 30, 31, 32, 33, 34, 36, 37, 39, 42, 43, 47, 56, 57, 59, 60, 62, 64, 65, 69, 70.