POWER PLANT FAMILIARISATION

CONTENTS

1. **Coal to Electricity**
2. **Main Boiler & Auxiliaries**
   - Boiler Fundamentals
   - Water Circulation System
   - Steam Circulation System
   - Arrangement of Boiler Auxiliaries
   - Air and Draft System
   - Fuel System & Fuel Gas System
   - Furnace Safeguard Supervisory System (FSSS)
3. **Main Turbine & Auxiliaries**
   - Steam Turbine Theory
   - Turbine Components
   - Arrangement of Turbine Auxiliaries
   - Vacuum & Condensate System
   - Feed Water & Auxiliary Steam System
   - Turbine Lubricating Oil System
4. **Generator & Auxiliaries**
   - Generator Fundamentals & its Components
   - Generator Cooling and Sealing System
   - Excitation System
   - Automatic Voltage Regulation
5. **Miscellaneous Facilities**
   - Coal Transportation & Handling
   - Fuel Oil System
   - Ash Handling Plant
   - Circulating Water System
   - Water Treatment Plant
   - Compressed Air System

1. Coal to Electricity

Basic Power Plant Cycle

A dual (vapour + liquid) phase closed cycle, is used in thermal power station to enable the repeated usage of water to generate steam. This also includes super heating of steam, regenerative feed water heating and reheating of steam.

Reheating increases the cycle efficiency on large turbines by partially overcoming temperature limitations. By returning partially expanded steam, to a reheat, the average temperature at which heat is added, is increased and, by expanding this reheated steam to the remaining stages of the turbine, the exhaust wetness is considerably less than it would otherwise be. For regenerative system, nos. of non-regulated extractions are taken from HP, IP turbine. Regenerative heating of the boiler feed water is used to increase the average temperature at which heat is added to the cycle, thus improving the cycle efficiency. Thermal cycle efficiency is affected by following:

- Initial steam Pressure and Temperature
- Reheat and it's pressure and temperature
- Condenser Pressure
- Regenerative feed water heating

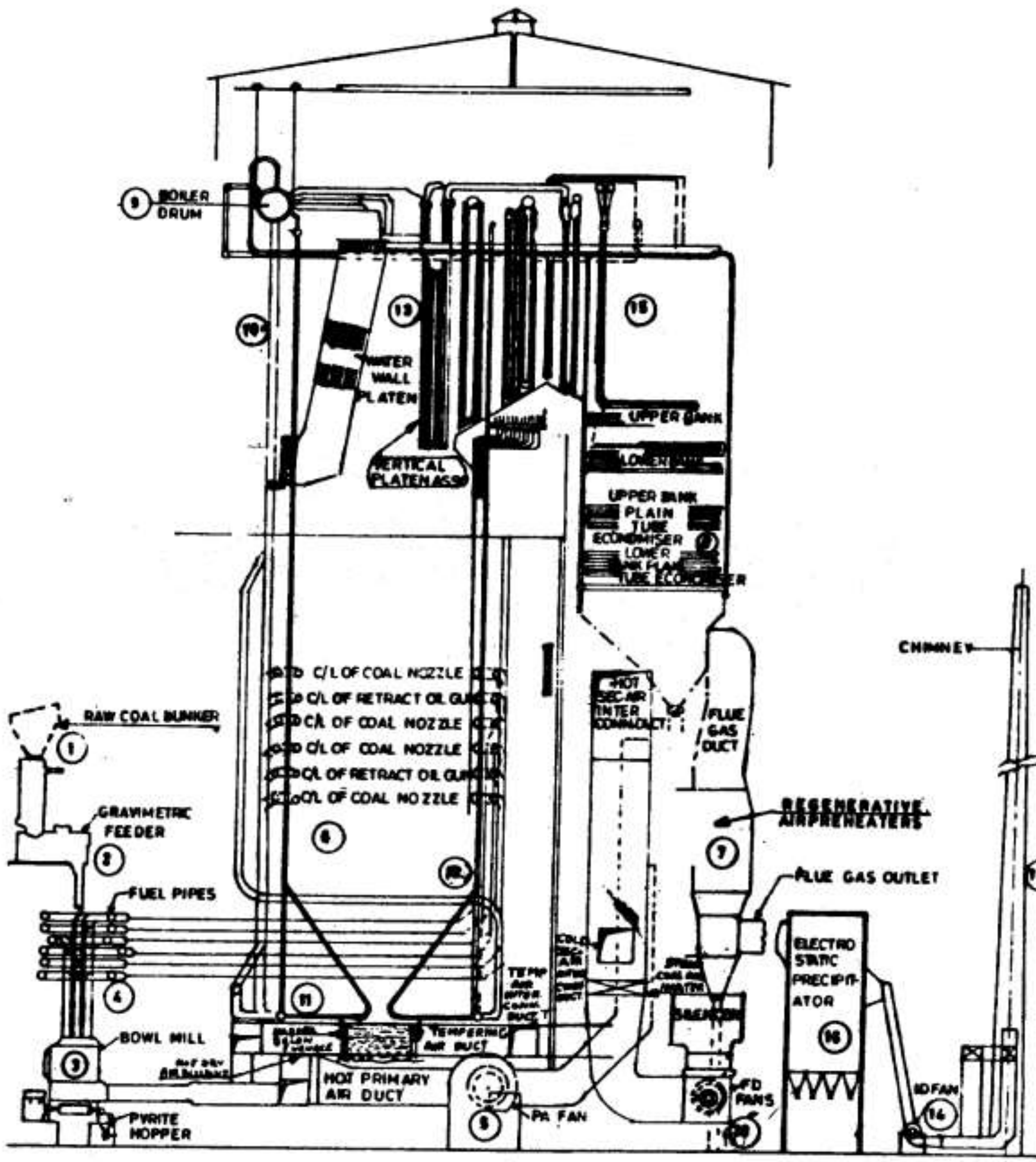
The conversion of coal into electricity in thermal power station mainly involves - generating steam from coal, conversion of thermal energy to mechanical power and generation and load dispatch of electric power.

Coal to Steam

First of all, the coal from the coal handling plant is transported to the raw coal bunkers and then to the Bowl Mills with the help of belt conveyors and coal feeders respectively. The coal is pulverised in the Bowl Mills, where it is ground to a powder form. Coal is crushed by the crushing action between the rollers and rotating table. This crushed coal is taken away to the furnace through coal pipes with the help of hot and cold air mixture from P.A. Fan. P.A. Fan takes atmospheric air, a part of which is sent to Air preheaters for heating while a part goes directly to the mill for temperature control. Atmospheric air from F.D. Fan is heated in the air heaters and sent to the furnace as combustion air.

Water from the boiler feed pump passes through economiser and reaches the boiler drum. Water from the drum passes through down commers and goes to bottom ring header. Water from the bottom ring header is divided to all the four sides of the furnace. Due to heat and- the density difference the water rises up in the water wall tubes. "Water is partly converted to steam as it rises up in the furnace. This steam and water mixture is again taken to the boiler drum where the steam is separated from water. Water follows the same path while the steam is sent to superheaters for superheating. The superheaters are located inside the furnace and the steam is superheated (540 degree C) and finally it goes to turbine.

Flue gases from the furnace are extracted by induced draft fan which maintains balance draft in the furnace (-5 to -10mm of wcl) with forced draft fan. These flue gases passes through various super heaters ,Reheater, economizer air preheater etc and release its heat energy and goes to electrostatic precipitator where the ash particles from flue gases are extracted. Electrostatic precipitator consists of metal plates which are electrically charged. Ash particles are attracted on to these plates, so that they do not pass through the chimney to pollute the atmosphere. Regular mechanical hammers blows cause the accumulation of ash to fall to the bottom of the precipitator where they are collected in a hopper for disposal. This ash is mixed with water to form slurry and is disposed to ash pond.



Steam to mechanical Power

Steam from boiler to the turbine is taken via steam pipes through stop valves and control valves. The control valves are required to regulate the amount of steam used depending upon the speed of the turbine and the amount of electricity required from the generator.These valves are located in a steam chest and a governor, driven from the main turbine shaft, operates these control valves.

Steam from the control valves enters the high pressure cylinder of the turbine, where it passes through a ring of stationary blades fixed to the cylinder wall. These act as nozzles and direct the steam into a second ring of moving blades mounted on a disc secured to the turbine shaft. This second ring turns the shafts as a result of the force of the steam. The stationary and moving blades together constitute a 'stage' of the turbine and in practice many stages are necessary, so that the cylinder contains a number of rings of stationary blades with rings of moving blades arranged between them. The steam passes through each stage in turn until it reaches the end of the high pressure cylinder and in its passage some of its heat energy is changed into mechanical energy.

The steam leaving the high pressure (HP) cylinder goes back to the boiler for reheating and returns by the reheat line to the intermediate pressure (IP) cylinder. Here it passes through another series of stationary and moving blades. Finally, the steam is taken to the low pressure (LP) cylinder, each of which it enters at the centre flowing outwards in opposite directions through the rows of turbine blades - an arrangement known as double flow - to the extremities of the cylinder. As the steam gives up its heat energy to drive the turbine, its temperature and pressure falls and it expands. Because of this expansion the blades are much larger and longer towards the low pressure ends of the turbine.

The turbine shaft usually rotates at 3,000 r.p.m. This speed is determined by below formula:

$$\text{Speed} = \frac{120}{P} \times f$$

where f-frequency, P- no. of poles of generator

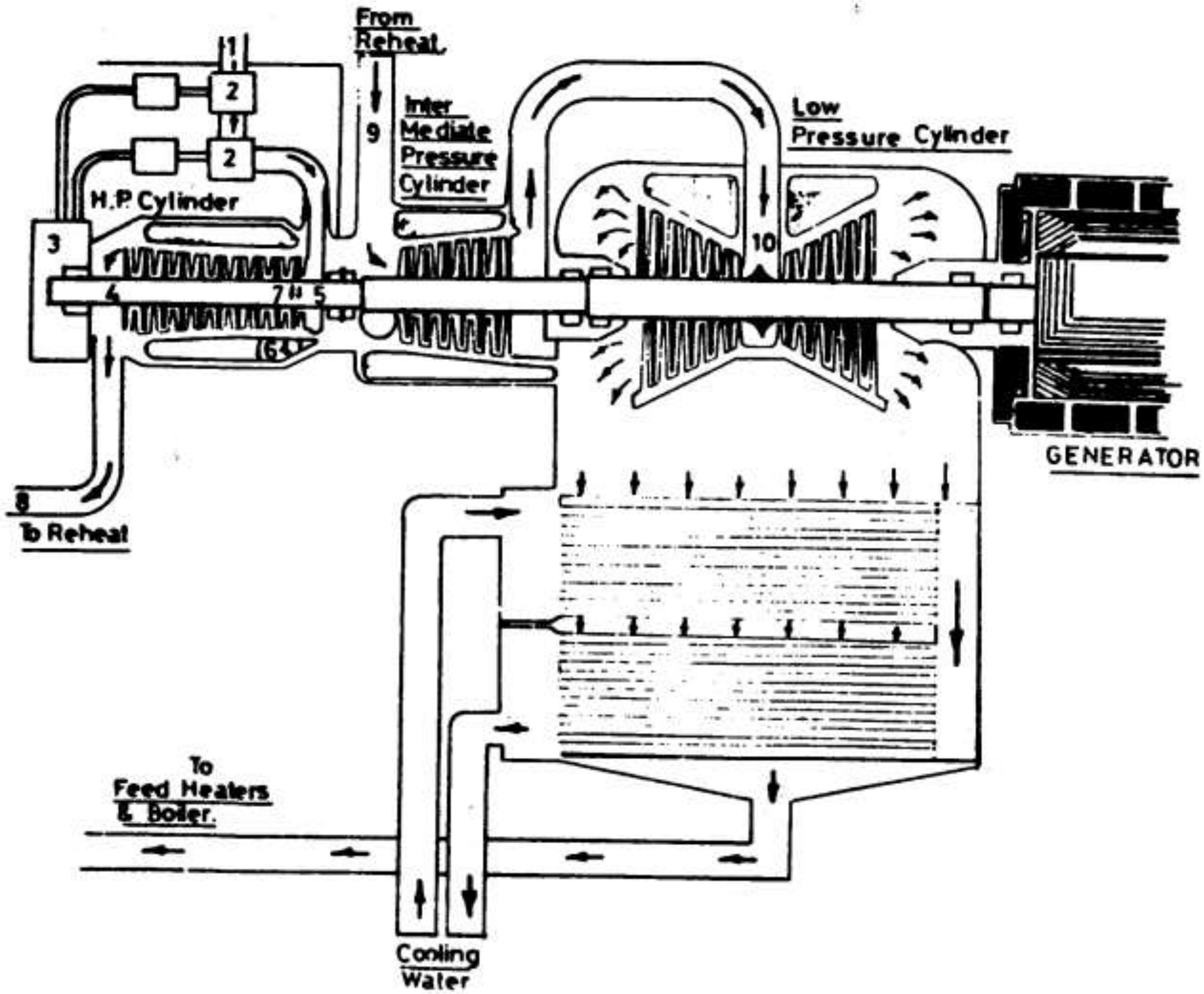
When as much energy as possible has been extracted from the steam it is exhausted directly to the condenser. This runs the length of the low-pressure part of the turbine and may be beneath or on either side of it. The condenser usually consists of a large vessel containing some 20,000 tubes, each about 25mm in diameter. Cold water from the river, estuary, sea or cooling tower is circulated through these tubes and as the steam from the turbine passes round them it is rapidly condensed into water condensate. Because water has a much smaller comparative volume than steam, a vacuum is created in the condenser. This allows the steam to reduce down to pressure below that of the normal atmosphere and more energy can be utilized.

From the condenser, the condensate is pumped through low pressure heaters by the extraction pump to the Deaerator, after which its pressure is raised to boiler pressure by the boiler feed pump. It is further passed through feed heaters , economiser and the boiler for re-conversion into steam.

Where the cooling water for power stations is drawn from large rivers, estuaries or the coast, it can be returned directly to the source after use. Power stations situated on smaller rivers and inland do not have such vast water resources available, so the cooling water is passed through cooling towers (where its heat is removed by evaporation) and re-used.

A power station generating 2,000,000 kilowatts (KW) of electricity requires about 2,27,500 cubic meters of water an hour for cooling purposes. Where cooling towers are used, about one hundredth part of the cooling water evaporates and a certain amount is returned to its source to carry away any impurities that collect. Most of it however, is re-circulated.

THE TURBO-GENERATOR



1 STEAM PIPE
2 CONTROL VALVES
3 GOVERNOR
4 TURBINE SHAFT
5 STATIONARY BLADES
6 CYLINDER WALL
7 MOVING BLADES
8 TO REHEAT
9 FROM REHEAT.
10 CENTRE OF L.P.T

Switching and Transmission

The electricity is usually generated in the stator windings of large generators at about 25 kV and is fed through terminal connections to one side of a generator transformer that steps up the voltage to 132/220/400 kV. Then, the conductors carry it to a series of three switches comprising an isolator, a circuit-breaker and another isolator.

Circuit-breaker is a heavy-duty switch capable of operating in a fraction of a second, is used to switch off the current flowing to the transmission lines. When electrical current is switched off by separating two contacts, an arc is created between them. At the very high voltages used for transmission, the size and power of the arc is considerable and it must be quickly quenched to prevent damage. Generally, circuit breakers with oil or compressed air as insulating medium are used to quickly quench the arch. Once the current has been interrupted the isolators can be opened. These isolate the circuit- breaker being applied to its terminals. Maintenance or repair work can then be carried out safely.

From the circuit-breaker the current is taken to the bus-bars conductors which run the length of the switching compound - and then to another circuit-breaker with its associated isolators, before being fed to the Grid.

Three wires are used in a 'three-phase' system for large power transmission as it is cheaper than the two wire 'single-phase' system that supplies the home .In the control room of power station, engineers monitor the output of electricity, supervising and controlling the operation of generating plant and high voltage switch gear and directing power to the Grid system as required. Instrument on the control panels show the output and condition which exits on all the main plant and a miniature diagram indicates the precise state of the electrical system.

2. Main Boiler & Auxiliaries

Boiler Fundamentals

Principles of Combustion

Fuel consists of carbon, hydrogen and sulphur as combustion elements. Combustion is brought about by combining carbon and hydrogen or hydrocarbons with the oxygen in air. When combustion is properly completed the exhaust gases will contain, carbon dioxide, water vapour, sulphur dioxide and a large volume of Nitrogen. When carbon burns completely, it results in the formation of carbon dioxide. When carbon burns incompletely, it forms carbon monoxide. Nitrogen does not burn but passes through the combustion chamber to the chimney unchanged excepting its temperature. Fuel is to be ignited by raising the temperature of the fuel to its ignition temperature.

The primary function of oil and coal burning systems in the process of steam generation is to provide controlled efficient conversion of the chemical energy of the fuel into heat energy which is then transferred to the heat absorbing surfaces of the steam generator.

The amount of air required to burn any fuel that is calculated by using the amount of the elements present in the fuel is known as the theoretical air. Practically, this quantity is not sufficient and extra air supplied is known as excess air. The loss of combustibles and un-burnt gas loss reduces as excess air is added, reaches a maximum and any further additions of excess air beyond this stage, the boiler losses increase. Thus, there is usually one and only one quantity of excess air, which will give the lowest combustion loss. The value of excess air needed depends upon the fuel used, the type of firing etc.

The following factors in efficient combustion are usually referred to as "The three T's”.

Time: Sufficient time must be allowed for proper ignition and complete combustion of the fuel in the chamber.

Temperature: A fuel has to reach its ignition temperature before it can burn. This temperature can be reached faster by preheating the combustion air. Also, the temperature of the flame of the burning fuel may lower with too much combustion air and may cause unstable ignition.

Turbulence: It has been observed that introducing turbulence produces a quick propagation of the flame and its rapid spread throughout the fuel/air mixture in the combustion chamber.

Combustion efficiency: The aim is to use correct quantity of air together with good mixing of fuel and air to obtain the maximum heat release. Combustion efficiency depends on boiler design, grade of fuel and skill in obtaining combustion with the minimum amount of excess air.

Thermal efficiency of a boiler is measured as:-

$$= \frac{\text{Amount of heat transferred to the water by one Kg of fuel}}{\text{Total heat energy in one Kg of fuel}} \times 100$$

Boilers

A steam boiler or steam generator is a closed vessel in which water is heated, vaporized and converted into steam at a high pressure.

Boiler is designed to transmit heat from an external combustion source (usually fuel combustion to a fluid) contained within the boiler itself. The heat generating unit includes a furnace in which the fuel is burned.

Boilers can be classified into two categories according to end use viz.

- Utility Boilers: Large capacity steam generators used purely for the electrical power generation
- Industrial Boilers : Mainly for use in the process industries and are further characterized as follows:
    1. Non-reheat units
    2. Bi-drum boilers having partial steam generation in the boiler bank tubes.

Arrangement of Main Boiler (200/210 MW)

The boiler accessories usually include:

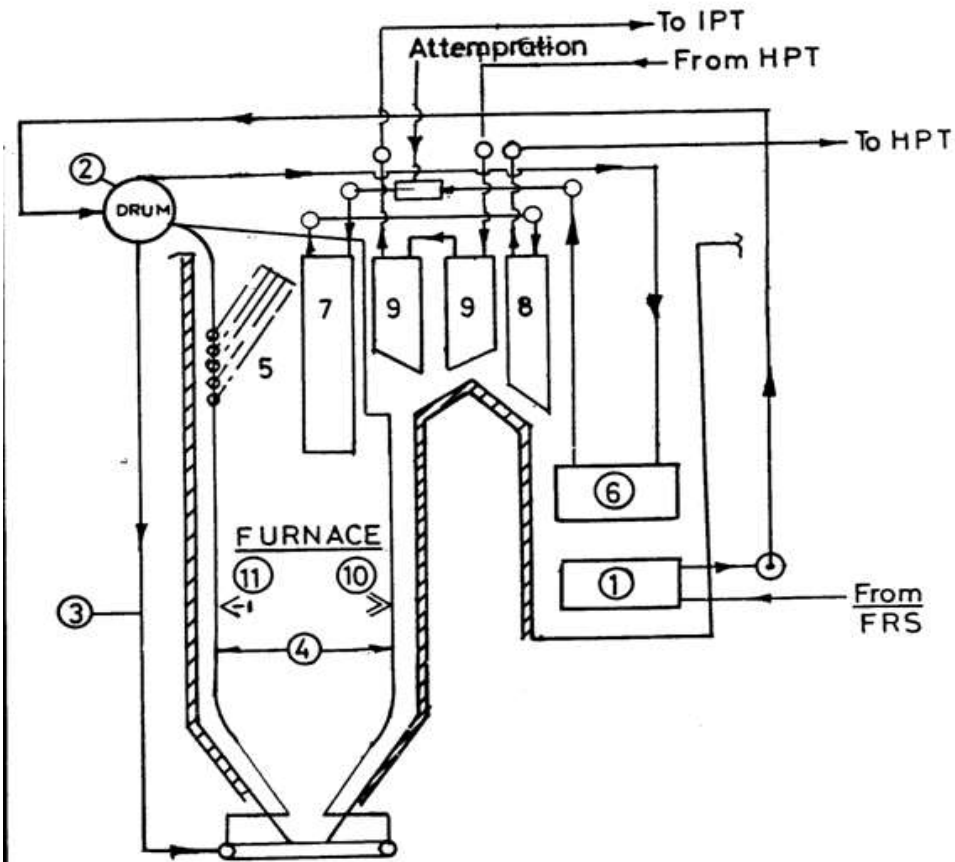
- Economiser
- Boiler drum
- Down Comers
- Water walls
- Water wall platen (used for Low Pressure Boilers)
- Primary super heater
- Platen super heater
- Final super heater
- Reheater
- Burner
- Ignitors

Furnace: It is a structure under or adjacent to a boiler in which fuel is burned and from which the combustion products pass into the boiler. It provides a chamber in which the combustion reaction can be isolated and confined so that the reaction remains a controlled force. In addition, it provides support or enclosure for the firing equipment.

Furnaces may be classified in terms of a construction feature or operating characteristics, general shape, design purpose or the fuel they burn.

The furnace must provide the following

- Proper installation, operation and maintenance of fuel burning equipment.
- Sufficient volume for combustion requirements.
- Adequate refractories and insulation.



1. ECONOMISER
2. BOILER DRUM
3. DOWN COMERS
4. WATER WALLS
5. WATER WALL PLATEN
6. PRIMARY SUPER HEATER
7. PLATEN SUPER HEATER
8. FINAL SUPER HEATER
9. REHEATER
10. BURNERS
11. IGNITORS

FRS. - FEED REGULATING STATION

Boiler Drum: The function of steam drum is to separate the water from the steam generated in the furnace walls and to reduce the dissolved solid contents of the steam to below the prescribed limit of 1 ppm. The drum is located on the upper front of boiler.

Economiser: The purpose of economiser is to preheat the boiler feed water before it is introduced into the steam drum by recovering heat from the flue gases leaving the boiler. The economiser is located in the boiler rear gas pass below the rear horizontal superheater. The economiser is continuous unfinned loop type and water flows in upward direction and gas in the downward direction.

Super Heater: There are three stages of superheater besides the side walls and extended sidewalls. The first stage consists of horizontal superheater of convection mixed flow type with upper and lower banks located above economiser assembly in the rear pass. The upper bank terminates into hanger tubes, which are connected to outlet header of the first stage superheater. The second stage superheater consists of pendant platen which is of radiant parallel flow type. The third stage superheater pendant spaced is of convection parallel flow type.

The outlet temperature and pressure of the steam coming out from the superheater is 540°C and 157 Kg/Cm^2 respectively for H.P.units.

Reheater: The function of reheater is to reheat the steam coming out from high pressure turbine to a temperature of 540°C. The reheater is composed of two sections. The front pendant section and rear pendant section.

The rear pendant section is located above the furnace arc and the rear water wall and front pendant section is located between the rear water hanger tubes and the superheater platen section.

Burners: There are total twenty four pulverised coal burners for corner fired C.E. type boilers and twelve oil burners provided each in between two pulverised fuel burner.

The pulverised coal burners are arranged in such a way that six mills supply the coal to the burners at 4 corners of the furnace. All the nozzles of the burners are inter-linked and can be tilted as a single unit from +30° to -30°. The oil burners are fed with fuel oil till boiler load reaches to about 25%.

Igniters: There are twelve side eddy plate oil/H.E.A igniters per boiler. The atomising air for ignitors are taken from plant air compressors at 7Kg/cm^2 (gauge). The burner are located at three elevations. Each elevation has four oil burners and ignitors. These elevations are normally known as AB elevation, CD elevation and EF elevation ,ignitors are used for lighting the main oil gun. There are two ignitor air fans supply air for combustion of ignitor oil. Mainly two types of ignitors are used.

- Eddy Plate Ignitor
- High Energy Arc Type Ignitors

The following facts must be born in mind to understand the ignitors and the system clearly :

- The spark rod life will be drastically reduced if left for long duration in the advanced condition when the furnace is hot.
- Too much retraction of spark rod inside the guide tube will interfere with nozzle tilts and may spoil the guide tube.
- A minimum discharge of 300 Kg/hr of oil is essential for a reliable ignition. A plugged oil gun tip may result in an unsuccessful start.
- A cold oil gun and hoses cause quenching of oil temperature and may lead to an unsuccessful start. In such cases, warming up by scavenging prior to start is necessary.

Water Circulation System

Theory of Circulation

Water must flow through the heat absorption surface of the boiler in order that it can be evaporated into steam. In drum type units (natural and controlled circulation) the water is circulated from the drum through the generating circuits and back to the drum where steam is separated and directed to the superheater. The water leaves the drum through the downcomers at a temperature slightly below saturation temperature. The flow through the furnace wall is at saturation temperature. Heat absorbed in water wall is latent heat of vaporization creating a mixture of steam and water. The ratio of the weight of water to the weight of steam in the mixture leaving the heat absorption surfaces is called Circulation Ratio. Circulation Ratio for utility boilers is between 6 to 9. Industrial boilers have a high circulation ratio. The value of CR varies from 8 to 30 in industrial boilers.

Types of Boiler Circulation System

The 3 systems of circulation are usually adopted in boilers :-

1. **Natural Circulation System**

The temperature of water delivered to a steam generator from feed heaters is much lower than the saturation value for that particular pressure. First, it enters the economiser where it is heated to about 30 to 40 deg C below saturation temperature. Then, the water enters the drum and flows down through the down comer and enters ring header at the bottom. In the water walls a part of the water is converted to steam and the mixture flows back to the drum. In the drum, the steam is separated, and sent to superheater for superheating and then sent to the H.P. turbine. Remaining water mixes with the incoming water from the economiser, and the cycle is repeated. This circulation is based on the thermo-siphon principle. The down comers contain relatively cold water, whereas the riser tubes contain a steam water mixture, whose density is comparatively less. This density difference is the driving force, for the mixture. Circulation takes place at such a rate that the driving force and frictional resistance in water wall are balanced.

As the pressure increases, the difference in density between water and steam reduces. Thus the hydrostatic head available will not be able to overcome the frictional resistance for a flow corresponding to the minimum requirement of cooling of water wall tubes. Therefore natural circulation is limited to boiler with drum operating pressure around 175 Kg/cm^2.

2. Controlled Circulation System

Beyond 180 Kg/cm2 of pressure, circulation is to be assisted with mechanical pumps, to overcome frictional losses. To regulate the flow through various tubes, orifice plates are used. This system is applicable in the high sub-critical regions (say 200 Kg/cm^2).

3. Combined Circulation System

Beyond the critical pressure, phase transformation is absent, and hence once through system is adopted. However, it has been found that even at supercritical pressure, it is advantageous to re-circulate the water through the furnace tubes at low loads. This protects the furnace tubes and simplifies the start-up procedure. A typical operating pressure for such a system is 260 Kg/cm^2.

Economiser

Economiser absorbs heat from the flue gases and add this heat to the feed water before the water enters the evaporative circuit of the boiler. Earlier, the economisers were introduced mainly to recover the heat available in flue gas that leaves the boiler. In the modern boilers, feed water heaters are used to increase the efficiency of turbine unit and feed water temperature, therefore, the relative size of economiser is less than earlier units. This is a good proposition as the heat available in boiler exit flue gas can be economically recovered using airheater which is essential for pulverised fuel fired boilers.

Location and Arrangements

It is usual to locate economiser, ahead of airheaters and following the primary superheater or reheater in the gas stream. Hence, it will be generally being contained in the same casing as the primary superheater or reheater. Counterflow arrangement is normally selected so that heating surface requirement is kept minimum for the same temperature drop in the flue gas. Economiser coils are designed for horizontal placement which facilitate drainings of the coil and favours the arrangement in the second pass of boiler. Water flow is from bottom to top so that steam if any formed during the heat transfer can move along with water and prevent the lock up steam which will cause overheating and failure of economiser tube.

Economiser tubes are supported in such a manner that sagging, undue deflection and expansion prevention will not occur at any condition of operation. A recirculation line with a stop valve and non-return valve may be incorporated to keep circulation in economiser into steam drum when there is fire in furnace but no feed flow. (e.g. During start-up). Tube elements composing the unit are built up into tiers or banks and these are connected to inlet and outlet headers. Manholes and adequate access and spacing between banks of tubes are provided for inspection and maintenance works. Normally the tube bank arrangement and steam soot blowers provision at appropriate location will facilitate efficient on load cleaning. An ash hopper below the economiser is provided if the flue gas duct is taking a turn from vertical.

Water Walls

In large boilers, water walls completely cover the interior surfaces of the furnace. Water walls serve as the only means of heating and evaporating the feed water supplied to the boiler from the economisers. Water walls usually consist of tangential vertical tubes and are connected at the top and the bottom to headers. These tubes receive water from the boiler drum by means of downcomers connected between drum and water walls lower header. In a boiler, approximately 50 percent of the heat released by the combustion of fuel in the furnace is absorbed by the water walls. Heat so absorbed by the water walls is used in evaporation of water supplied to the boiler. The mixture of steam and water is discharged from the top of the water walls tubes into the upper wall header and then passes through riser tubes to the steam drum. Here, the steam is separated and the accompanying water together with the incoming feed water is returned to the water walls through the down comers.

The water walls may be of following construction:

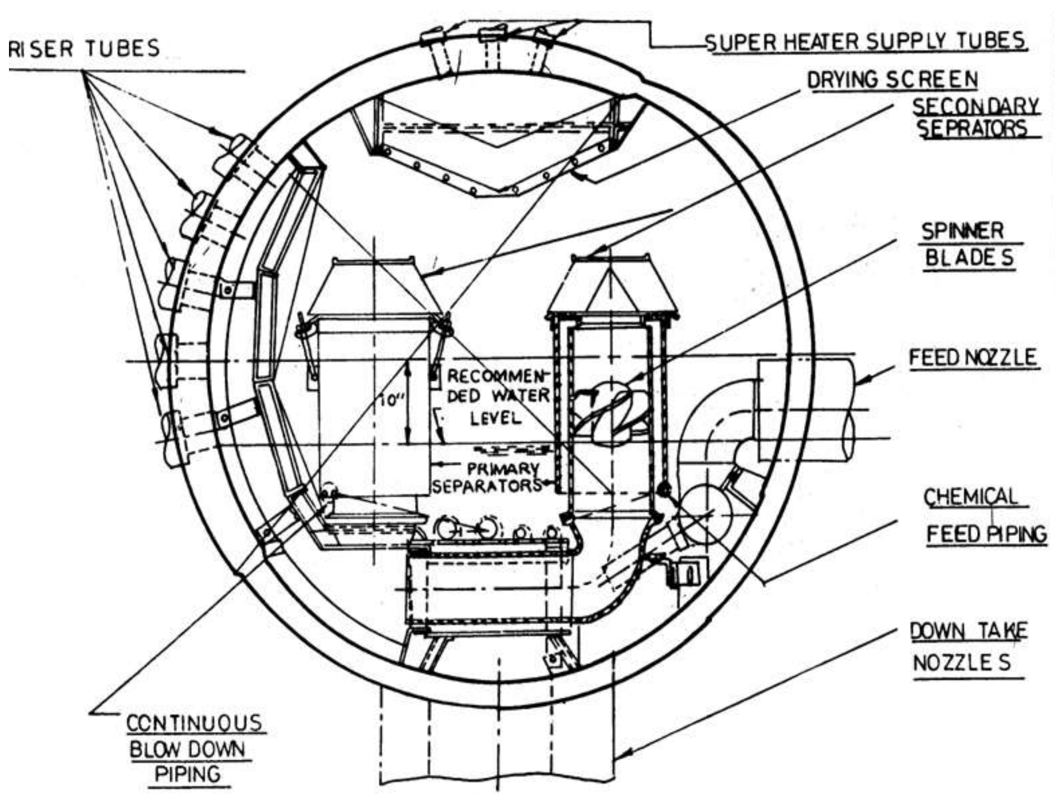
- Tangent tube construction : In this, water wall is placed side by side nearly touching each other. "SKIN CASING", an envelope of thin steel sheet, is placed in contact with the tubes to provide a seal against furnace leakage
- Membrane wall construction : In this type, a number of tubes are joined by a process of fusion welding or by means of steel strips called 'fins'.

Drum & Drum Internals

Steam and water Drum: The boiler drum is a part of the circulation system of the boiler. The drum serves two functions- one is separating steam from the mixture of water and steam discharged into it and other is purification of steam after being separated from water. This purification equipment, that drum contains, is commonly referred to as the drum Internals.

Since the quantity of water contained in the boiler below the water level is relatively small compared to the total steam output, therefore, the matter of water storage is not significant. Primarily, the drum size is determined by the space required to accommodate the steam separating and purifying equipment. The steam space provided should be sufficient to prevent priming & foaming. Drum diameter and length should be sufficient to provide accessibility for installation, inspection and servicing of the drum internals. In most cases, the drum length generally depends on furnace width or in high capacity units it may be governed by the space required for steam separating devices. For this purpose, the drum length is kept at least 900 mm more than the furnace width. The thickness of the drum is designed taking into consideration, the operating parameters, the diameter and location of the various holes on the drum.

Steam generated is mixed with large and variable amounts of circulating boiler water. All of this associated boiler water must be separated from the steam before the steam leaves the boiler drum and enters the superheater.



Materials: The boiler drum is made of carbon steel plates because cost per ton is less than alloy steel. Also, fabrication and welding is easier.

Drum Internals

Drum internals are used to separate water from steam and to direct the flow of water and steam such that there is optimum distribution of temperature. The drum internals may consist of:-

- Baffle arrangements
- Devices which change the direction of flow of steam and water mixture
- Separators employing spinning action for removing water from steam
- Steam purifiers as washers and screen dryers.

The arrangement of drum normally consists of two or more integrated devices, each of which may be quite different in design and operate on totally different principles. Each stage must have high separation efficiency. The greater the number of stages of separation, the lower the required efficiency for each stage. Thus, two stages at 99 percent efficiency, three stages at 90 percent efficiency and six stages at 70 percent efficiency will give similar results. With increase in pressure, the separation of water from steam by simple devices becomes more difficult.

Steam Circulation System

Riser Tubes: A riser is a tube through which water and steam pass from an upper waterwall header to a steam drum.

Superheater: Superheaters are usually classified according to the shape of the tube banks and the position of the header; also according to whether they receive heat by radiation or convention, although in some instance it may be a combination of both methods.

Types of superheaters: Depending on the firing method, fuel fired etc., the superheaters are placed in the boiler flue passes, horizontally, vertically or combined.

1. Pendant type: The superheaters may be of pendant type, hanging from and supported by their headers.
2. Horizontal type: In these, tubes are arranged across the boiler. These are self-draining which is an advantage during lighting up. The platen is a plane surface receiving heat from both sides. The ratio of longitudnal pitching to transfer pitching is very low for platen superheater.
3. Radiant Superheater: Radiant superheater absorbs heat by direct radiation from the furnace and are generally located at the top of the furnace. In some older designs, the superheater tubes form part of the furnace wall and receive practically all the heat of radiation.
4. Convection Superheater: Convection superheaters absorb heat mainly by the impingement of flow of hot gas around the tubes.
5. Combined Superheater: A combination of the falling steam temperature characteristic of the radiant superheater, together with the rising characteristic of the convection superheater is used in most of the installations for the purpose of maintaining constant steam temperature. It has the advantages of providing a constant steam temperature over a very wide range in load. This illustrates the performance that may be expected when the two types of surfaces are properly proportioned.

Desuperheater/Attemperator

Desuperheating or attemperation is the reduction or removal of superheat from steam to the extent required.

As mentioned earlier, the characteristic performance of a superheater which receives its heat through convection from gas flowing over it, is rising temperature with increasing output. To obtain some degree of control, the superheater must be designed for full temperature at some partial load. As a result, there will be excessive surface, with corresponding excess temperatures at higher loads.

The preferred location of desuperheater, especially for temperature above 450 deg C is between sections of superheater. In such installations, the steam is first passed through a primary superheater where it is raised to some intermediate temperature. It is then passed through the desuperheater and its temperature reduction is controlled so that, after continuing through the secondary or final stage of the superheater, the required constant conditions are maintained at the outlet.
Desuperheaters are either non-contact or direct contact type.

Reheaters

This is the part of the boiler which receives steam back from the turbine after it has given up some of its heat energy in the high pressure section of the turbine. The reheater raises the temperature of this steam, usually to its original value, for further expansion in the turbine. The purpose of this reheating is to add energy to the partially used steam.

The arrangement and construction of a reheater is similar to that of a superheater. In large modern boiler plant, the reheat sections are mixed equally with superheater sections. The reheat sections in modern boilers usually consists of pendant assemblies. These can be used in combination with horizontal assemblies or a radiant wall located in the upper furnace.

The cold reheat is not cold to the sense of touch, but is the line from turbine to the boiler and is at a temperature lower than the reheat line from boiler to the turbine called hot reheat steam. Due to resistance of flow through the reheat section, the hot reheat steam is at lower pressure compared to the cold reheat steam.

Arrangement of Boiler Auxiliaries

Coal Bunker: These are in process storage silos used for storing crushed coal from the coal handling system. Generally, these are made up of welded steel plates.' Normally, there are six such bunkers supplying coal of the corresponding mills. These are located on top of the mills so as to aid in gravity feeding of coal.

Coal Feeders : Each mill is provided with a drag link chain/rotary/gravametric feeder to transport raw coal from the bunker to the inlet chute, leading to mill at a desired rate.

Mills : Mills pulverize coal to the desired fineness to be fed to the furnace for combustion. There are six mill (25% capacity each), for every 200 MW unit, located adjacent to the furnace at '0' M level.

P.A. Fan : The primary air fans (2 per unit - 50% capacity each) are designed for handling atmospheric air upto a temperature of 50 deg C. These fans are located at '0' M level near the boiler.

Air Pre-heater : Air pre-heater transfer heat from flue gases to cold primary and/ or secondary air by means of rotating heating surface elements. Beneath this regenerative type air pre-heaters, there exists a steam coil air pre-heater. These are located in the secondary pass of the furnace. Each 200/210 MW unit is usually provided with two such air pre-heaters.

Burners : These are used for burning pulverised coal or oil. Every unit has a set of such burners located at different elevations of the furnace.

F.D. Fan: The forced draft fans (2 per unit - 50% capacity each) are designed for handling secondary air for the boiler. These fans are located at '0' M level near the PA Fan.

Wind Box: These are located on the left & right sides of the furnace while facing the chimney and supply excess air to the furnace for combustion.

Scanner Fan: These fans, two per boiler, supply requisite air for scanner cooling.

Ignitor Fan : These fans, again two per boiler, are used to supply air for cooling ignitors and combustion of ignitor air fuel mixture.

Electrostatic precipitator : These are generally two plate type , located between boiler and the chimney. The precipitator is arranged for horizontal gas flow and is constructed with welded steel casings.

ID Fans : These are located between the Electrostatic precipitator and the chimney. These fans are used for sucking flue gas from furnace.

Chimney : These are tall RCC structures, anywhere between 150 m. to 220 m, with single/multiple flues.

Seal air Fan : These are used for supplying seal air to the mills to prevent ingress of coal dust into gear box lubrication oil. There are two fans per boiler for 200 MW units.

Soot Blowers: Following three types of soot blowers, in requisite numbers, are provided :

i Long retractable soot blowers
ii Wall blower
iii Air heater blower

Superheated steam is tapped from superheater for the purpose of soot blowing.

The pressure is reduced to 31 Kg/cm2 at 330 deg C by means of pressure reducing valve. The soot blowers are used for efficient on-load cleaning of furnace, superheaters, reheaters and regenerative air heaters.

Air and Draft System

Basics of Fans

A fan is used to impart energy to the air/gas in the form of a boost in pressure needed for a variety of tasks, for example, to evacuate flue gas or for combustion in the furnace. The boost is dependent on density for a given fan at a given speed. The higher the temperature, the lower is the boost. Fan performance (Max. capability) is represented as volume vs pressure boost. The basic information needed to select a fan are :

- Air or Gas flow -Kg/hr
- Density (function of temperature and pressure)
- System, resistance (losses)

Classification of Fans

In boiler practice, we meet the following types of fans.

- Axial fans
- Centrifugal (Radial) fans

Axial Fan: In this type, the movement of air or gas is parallel to its axis of rotation. These fans are better suited to low resistance applications. The axial flow fan uses the screw like action of a multibladed rotating shaft, or propeller, to move air or gas in a straight - through path. Axial fans can be of two types:-

- Impulse type
- Reaction type

Radial Fan: This fan moves gas or air perpendicular to the axis of rotation. There are advantages when the air must be moved in a system where the frictional resistance is relatively high. The blade wheel whirls air centrifugally between each pair of blades and forces it out peripherally at high velocity and high static pressure. More air is sucked in at the eye of the impeller. As the air leaves the revolving blade tips, part of its velocity is converted into additional static pressure by scroll shaped housing. Radial Fan can be of three types depending on types of blades:-

- Backward curved blades
- Forward curved blades
- Radial blades

Draft System

Draft denotes the difference between the atmospheric pressure and the pressure existing in the furnace. Depending upon the draft used, we have

- Natural Draft
- Induced Draft
- Forced Draft and
- Balanced Draft System

Natural Draft : The pressure differentials are obtained by constructing tall chimneys so that vacuum is created in the furnace and air is admitted into the furnace.

Induced Draft : The air enters due to natural pressure difference and the flue gases are taken out by means of induced Draft fans and the furnace is maintained under vacuum.

Forced Draft: Forced draft fans supply air to the furnace, so the furnace is pressurized. The flue gases are taken out due to the pressure difference between the furnace and the atmosphere.

Balance Draft: Most of the power stations utilize both Induced and Forced Draft Fans in maintaining a vacuum in the furnace.

Industrial Fans

I.D. Fan: The induced Draft Fans are generally of Axial-Impulse Type. Impeller nominal diameter is of the order of 2500 mm. The fan consists of the following sub-assemblies :-

- Suction Chamber
- Inlet Vane Control
- Impeller
- Outlet Guide Vane Assembly
- Diffuser
- Bearings

The outlet guides are fixed in between the case of the diffuser and the casing. These guide vanes serve to direct the flow axially and to stabilize the draft-flow caused in the impeller. These outlet blades are removable type from outside and can be replaced during operation.

The bearings are self-aligning roller type. The flanged bearing on the impeller side is the fixed bearing and the outlet bearing is the expansion bearing. Both the bearings are grease lubricated. A grease quantity control ring is provided in each bearing to discharge the surplus amount of grease. For controlling the bearing temperature, a contact tele-thermometer is provided in the bearing. The contacts are to be set at 80 deg C for signaling and to 90 deg C for stopping the main motor. A cooling pipe for cooling the inner bearing is provided.

Flexible Coupling : Coupling between the motor and fan is flexible pin type with rubber bush inserts.

F.D Fan: The fan, normally of the same type as ID Fan, consists of :-

- Silencer
- Inlet bend
- Fan housing
- Impeller with blades and setting mechanism
- Guide wheel casing with guide vanes and diffuser.

The centrifugal and setting forces of the blades are taken up by the blade bearings. The blade shafts are placed in combined radial and axial antifriction bearings which are sealed off to the outside.

The angle of incidence of the blades and the characteristic pressure volume curves of the fan may be changed in a large range as per operating condition without affecting efficiency. The rotor is accommodated in cylindrical roller bearings and an inclined ball bearing at the drive side adsorbs the axial thrust. Lubrication and cooling of these bearings is assured by a combined oil level and circulating lubrication system.

Primary Air Fan : P.A. fan is flange mounted design, single stage suction, NDFV type, backward curved bladed radial fan operating on the principle of energy transformation due to centrifugal forces. Part of velocity energy is converted to pressure energy in the spiral casing. The fan is driven at a constant speed and the flow is controlled by varying the angle of the inlet vane control. The Special feature of the fan is that it is provided with inlet guide vane control with a positive and precise link mechanism. It is robust in construction for higher peripheral speed so as to have unit sizes. Fan can develop high pressures at low and medium volumes and can handle hot air laden with dust particles. The fan consists of the following sub assemblies:

Suction Chamber: It is of welded sheet steel construction and split horizontally for each assembly and dismantling. Manholes are provided for inspection of the same.

Inlet Vane Control: It consists of a number of aerofoil fixed to individual shaft, which are connected by means of angular joints to a central ring. The rig is guided to rotating position by a set of roller and spring assemblies. A control lever is connected to a ring which can be operated by an electric servomotor or a pneumatic power cylinder.

Rotor: The rotor consists of a shaft and impeller. The impeller is mounted on a shaft with a taper fit and locking nut. The critical speed is maintained well above operating speed.

Housing: The spiral casing is of two part design. Casing and outlet have rectangular cross section. Lower part of casing rests on supporting brackets on the foundation.

Bearings: The fan rotor is placed in cylindered roller antifriction bearings. An inclined ball bearing absorbs the axial thrust on the impeller side and scrapper rings seal off the bearing casing. For controlling the bearing temperature, thermometers are provided in the bearings.

Flexible Coupling: Coupling is of flexible pin type with rubber bush inserts.

Shaft-Seal: It is a two part-labyrinth seal which seals off the box section casing at the shaft passage.

Ignitor Air Fan

Ignitor fan provides necessary combustion air from atmosphere to the wind boxes of individual igniters at a fixed constant uncontrolled rate at ambient temperature. Fan impeller is directly mounted on the motor shaft and installed in the casing. Casing is so designed that one side panel (cover) can be easily removed off by loosening the fixing bolts. Dampers are provided and flanged at inlet and outlet of fan to control the air flow.

Scanner Air Fan

Scanner fans are installed in the boiler for supplying cooling air to the flame scanner provided for flame supervision. Normally one fan remains in service while the other one remains available as stand-by. Scanner air fan is centrifugal type and impeller is directly on the motor shaft with the help of hub. Sets of dampers are mounted at inlet and outlet of the fan. The scanner air fan takes its suction from F.D. fan outlet.

Control of Fan Output

1. Variable Speed Control: Speed variation of fan also varies the quantity and pressure developed in proportion to the load and square of the load.

2. Inlet Vane Control: In the case of axial fans, the variation in output is achieved by changing of angle of inlet with respect to the moving blades.

3. Damper Regulation: In this method a damper is introduced in the circuit and by varying the damper opening the resistance offered by it is altered.

4. Variable Pitch type: This is applicable only to variable pitch type axial fan. The blade itself is rotated such that optimum efficiency can be maintained at part loads also.

Fuel System & Fuel Gas System

FUEL SYSTEM

Feeders

In most of the power stations the types of feeders used for transporting coal from RC bunker to the mills are

- Volumetric feeders
    - Chain feeders
    - Belt feeders
    - Table type rotary feeders
- Gravimetric type feeders

In chain type of feeders, a continuous chain is moving round the sprockets in which a sprocket is driven by a variable speed DC motor and the other sprocket is a return sprocket. On this chain, at different intervals, MS plates are connected which are called as scrapers. This type of chain feeders is called scraper feeders. The Coal from the RC bunker falls on a platform, which is below the scraper feeder. When the scraper moves it will scrap the coal and at the end of the table or platform the coal falls into the pulverizer. The actual fuel bed thickness carried by the scrapers will be more. To restrict this, a height regulating plate is provided so that height of fuel scraped by the scraper can be controlled.

In belt feeders a continuous belt is running. The belt is directly carrying the load of the fuel. Here, the fuel can be controlled by the speed of the conveyor belt or the height of the fuel bed. In all the cases for easy control of the speed of the either scraper feeders or belt feeders, DC motor is used.

Rotary feeders are just similar to the paddle feeders or blade feeders. This load on to conveyor and the conveyors discharge the fuel into the pulverizers.

Gravimetric Coal Feeder: Gravimetric Coal feeder is used for feeding the Coal from the bunker to pulveriser as per requirement. At the time of operation, plate injects coal flow and saves conveyor belt from direct in-feed impact. Plate can be taken out at the time of pluggage or any other problem and heavy part can be replaced. Front portion of in feed is always slotted in angle so that it could open when coal reaches at well. This in- feed opens all by itself during rotation and there is no chance of its getting jammed. Coal is dropped on belt at an angle to an in-feed dresser linker with the coupling.

Mills

Pulverised fuel firing is a method whereby the crushed coal, generally reduced to a fineness such that 70-80% passes through a 200 mesh sieve, is carried forward by air through pipes directly to burners or storage bins from where it is passed to burners. When discharged into combustion chamber, the mixture of air and coal ignites and burns in suspension.

The economic motives for the introduction and development of pulverised fuel firing are:

- Efficient utilization of cheaper low grade coals.
- Flexibility in firing with ability to meet fluctuating loads.
- Elimination of banking losses.
- Better reaction to automatic control.
- Ability to use high combustion air temperature; increasing the overall efficiency of boiler.
- High availability.

The only disadvantage is that the initial cost of equipment for preparation of pulverised coal will be high.

Types of pulverisers : Milling plant may be divided into three main types - low, medium and high speed; each having its own advantages and drawbacks.

Low Speed Mill

These are commonly known as tube ball mill and operate at approximately 17 to 20 rev/min. Such low speed is essential with this type of mill as otherwise the balls will be held along the rotating surface due to centrifugal force and no milling can take place. Major advantage of the mill is that the wearable part, which needs replacement between annual overhauls, is only the ball and this can be done when mill is in operation. Hence availability of each mill can reach 100% of the boiler availability. However, the gearbox and main bearing failure may reduce the availability. The main disadvantage is that the power consumed per ton of coal pulverised is nearly twice that of the economic mills such as bowl mills In addition to this power consumption is practically constant whatever may be the load at which mill is operated thus calling for operation at or near full load to achieve economy in operating cost. Spare mill for maintenance purpose is not necessary due to high availability. Even though this mill requires higher floor area, foundation and initial cost of equipment, it is preferred by some customers because of high reliability coupled with low maintenance.

Medium Speed Mills

This is normally of vertical spindle design and operate between 30 to 100 rpm. Combustion Engineering's Bowl Mill, B & W's ball and race mill and other designs are available in the market. These are suitable for both pressurized and suction operation. These are most economic mills with regard to operating cost since comparatively small mass is being rotated at moderate speed. Replacement of wearable parts in between annual overhauls is essential and is facilitated by the design of mill and availability of spare mill for each boiler. The mills of varying capacities from 1 to 100 t/hr and even more have been designed and are in operation Power consumption varies with loading on mill which offers maximum efficiency when used in direct firing. In addition to the saving in operating cost, it requires less space and less initial foundation cost, thus the mill is seen increasingly used throughout the world.

High Speed Mill

This mill is directly coupled to the motor, thus eliminating speed reduction gears essential for the other types. This is run at 500 to 1000 rpm depending upon design Beater mill, impact mill etc. are of this design.

Bowl Mill

The bowl mill is one of the most advanced designs of coal pulverizer presently manufactured. The advantages of this mill are:

- Lower power Consumption: Low mass of grinding elements, and quick removal of ground material by flowing air assure low power consumption.

- Reliability: A pulveriser designed should be reliable in operation to meet the demand of the steam generating units and the bowl mills are considered more reliable in this aspect.

- Minimum Maintenance: Frequency and length of the pulveriser outage must be kept to an absolute minimum to ensure that large blocks of generating capacity are not lost during peak load periods, there is bound to be an associated wear of mill components during grinding. Unique grinding method and materials of wear parts used minimise wear to greater extent. Replacement of parts involves minimum downtime because of the ease with which the equipment can be taken apart and reassembled.
- Wide Capacity: Capacities of various ranges are available from 1.7 t/hr. to 100 t/ hr.

Design Features of a Bowl Mill involves high temperature air flow upto 440 deg C enabling the mills efficiently dry, grind and classify high moisture coals.

Firing Systems

This can be broadly classified into direct firing system and indirect firing or intermediate bunker system. Both the systems can use any type of mill. Either hot gas or air can be used for drying and transporting the coal.

Direct Firing System: Coal is fed to the mill at controlled quantity. Hot air whose temperature can be controlled with the help of cold air is permitted to flow through the mill. The air dries the coal and picks up the milled product and flows through the classifier where higher size particle is rejected back to the mill. The fine coal is carried by the air through the coal burner to the combustion chamber. The flow through the system is carried out by primary air fan or by exhauster. In case of hammer mills, forced draft itself can do the purpose of primary air fan.

This system is simple involving minimum equipment hence minimum initial cost and maintenance cost. As there is no fine coal storage the mill load is varied according to the boiler load. Hence part load operation of mill is essential and this means increase in power consumption and maintenance per tonne of coal. Mill outage will result in reduction of boiler output if spare mills are not provided or available. This is best suited to use with high speed and medium speed mills as the mill power consumption varies in direct proportion to the mill load. Tube ball mills with this system is also used but to a limited extent.

Indirect Firing System: Mills are operated independent of boiler loading and pulverised coal is stored in the intermediate bunker. From the bunker it is taken to combustion chamber with the help of primary air fan. Boiler loading is controlled by the amount of pulverised fuel fed to boiler.

Hot air or gas is used for drying and transporting. Cyclone type separators are used to separate the fine coal from coal, air/gas mixture for storing in fine coal bunker. As fine coal dust cannot be completely removed by cyclone type separators, a certain portion of very fine particle is carried along by air/vapour. This necessitates admissions of vapour/air into the combustion chamber to utilise the heating value of fine coal dust carried along with vapour/air. This can be done by providing separate vapour burners or the air can be used as primary air for carrying the fine coal.

This system using gas as drying medium requires one additional fan called vapour fan for each mill. If air is used for drying, one fan called mill fan can be designed to carry out both the functions of primary air fan and vapour fan.

This system favors the following advantages:

- Mill can be operated always at full load, thus saving in power, maintenance cost per tonne of coal for the selected mill. Hence this system is adopted normally for tube ball mill.
- Separate spare mill is not necessary for carrying out the maintenance. Certain percentage as spare capacity on total basis is normally enough.
- Mills can be operated during off peak hours only and hence higher power out during the peak period.

Methods of Fuel Firing: There are many ways of firing the coal in furnace. They are:

- Vertical firing
- Horizontal firing
- Impact firing
- Corner or tangential firing

Vertical firing: In vertical firing, a number of rectangular fan shaped nozzles are set across the width of the furnace in an arch immediately under the boiler setting. The Pulverised fuel mixture ignites under the arch and is directed vertically downwards to the bottom of the furnace where the gases are made to turn upwards to pass through the combustion chamber this gives a long path to the flame and is particularly suitable for coals of low volatile content.

Horizontal Firing (Front Firing) : Horizontal firing with the turbulent type of burner are set up usually in the front (front wall fired) or rear walls of the furnace. This burner consists of an inner cone for primary air and fuel which is given a rotary motion as it passes through the burner. This mixes with a stream of rotating secondary air before burning.

Impact Firing : This is the arrangement with the type of burner used with slag tap furnaces where the ash is kept in a molten state on the furnace floor and tapped off as and when necessary.

Corner or tangential firing : In this system, burners are set at each corner of the furnace and are directed to strike the outside of an imaginary circle in the centre of the furnace. Because the streams of fuel so strike each other, extremely good mixing is obtained. Since the body of the flame produced is given a rotary motion it leads to a longer flame travel and the gases spread out-and flows through combustion chamber.

Burners & Burner Arrangement

Oil burner design considerations: The essential requirement for an oil burner design are:

- It must completely atomise the oil without -drooling, fouling or clogging.
- The jet must be so shaped that it will completely mix with the air necessary for combustion.

- Maintenance of atomisation over a comparatively wide capacity range.
- Combustion must be complete and excess air at a minimum over the entire operating range.
- A ready accessibility for effecting repairs, thereby minimizing burner outage as well as maintenance costs.

Atomisation: Atomisation breaks the fuel into fine particles that readily mixes with the air for combustion. Oil should be divided up into small particles for effective atomisation. The advantages of atomisation are:

- Atomising burners can be used with heavier grades of oil.
- Can be adopted to large applications because of large capacity range.
- Complete combustion is assured by the ability of the small particles to penetrate turbulent combustion.

Classification:-

- Air-atomised burners
- Steam -atomised burners
- Mechanically atomised burners

Air Atomising System: The air atomising system uses compressed air at 7 kg/ sq.cm. The quantity of air' required depends on design of burner, degree of automisation required, grade of oil, its pressure and temperature. The air used in the system should be free of condensate. Air atomising system is not recommended for heavy oil system as they tend to chill the oil and decrease atomisation quality. The guns used in this system have two main components for atomisation. They are:

- Mixing plate
- Spray Plate.

The role of mixing plate is to mix the air and oil properly and the role of spray plate is to inject this mixture uniformly into the furnace.

Mechanical atomisation Oil under pressure is supply to the burner gun and enters the atomiser tip through slots cut tangentially to the periphery of the Whirling. The drop pressure is converted into velocity causing the oil to enter the whirling chamber at a very high speed, thus establishing a rapid rotation of the oil in the whirling chamber. Since the mechanical atomisation oil guns are limited in range they are generally selected for boiler operating at fixed loads.

Steam Atomisation This System uses auxiliary steam to assist in the atomisation of the oil. The steam used in this method should be slightly superheated and free of moisture. As in the air atomising system, the steam used for atomising as well as the fuel pass through the tip and into the furnace. The main advantages of steam atomising burners over other are:

- Simplicity of its design
- Initial cost of installation is low
- Low pumping pressure
- Low preheating temperature.

The only disadvantage is the steam consumption in burners.

The types of oil used in the oil burners are:

- Light Diesel Oil
- Heavy fuel oil
- Low sulpher heavy stock (LSHS).

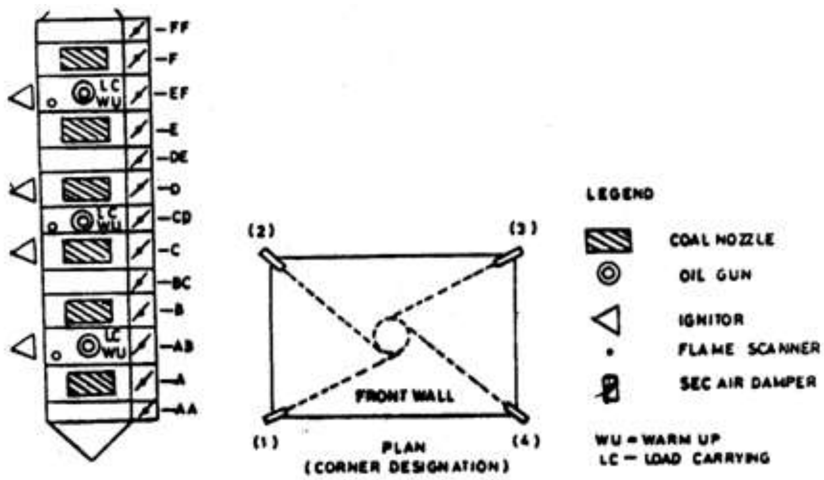
Heavy oil guns are used for stabilizing flame at low load carrying. Warm up oil guns are used for cold boiler warm up during cold start up and ignitor are used for start up and oil flame stabilizing.

Coal Burners Coal burners mainly comprise of coal nozzle, steel tip, seal plate and tilting link mechanism. These are housed in coal compartment in all four corners of the furnace and connected with coal pipes. Coal nozzle's one end (outlet) is rectangular and another end is cylindrical. The rectangular end which forms the nozzle is connected with nozzle tip by pivot pin. The tip can be tilted on this pivot. The nozzle tip is divided into several sectors to form separate coal and air passages. Again, coal and air passages is divided into sevaral parts for uniform distribution of flow. To seal the air and coal passage, a seal plate is provided.

Burner Arrangement

There are twenty four pulverised coal burners arranged on the corners at a height of 18 to 25 meters and twelve oil burners provided each in between two pulverised fuel burners.

The pulverised coal burners are arranged in such a way that six mills supply the coal to burners at 4 corners, of the furnace, all the nozzle of the burners are inter linked and can be tilted as a single unit from +30 deg. to -30 degree.
The oil burners are fed with heavy fuel oil till boiler load reaches to about 25%. There are four wind boxes fixed at 4 corners of the furnace. There are 13 nozzle in each wind box 6 for coal and 7 for air.



FUEL GAS SYSTEM

Air Heater

Air heater is used to raise air temperature by transferring heat from other media such as Hue gas. By reclaiming heat from flue gas at low temperature levels, the heat rejected to chimney can be reduced to higher extent thus increasing the efficiency of the boiler. For every 20 deg.C drop in flue gas exist temperature, the boiler efficiency increases by about 1%.

Advantages of Airheaters In addition to increase in boiler efficiency the other advantages that may result are listed below:

- Stability of Combustion is improved by use of hot air.
- Intensified and improved combustion.
- Permitting to burn poor quality coal.
- High heat transfer rate in the furnace and hence lesser heat transfer area requirement.
- Less unburnt fuel particle in flue gas thus combustion and both efficiency is improved.
- Intensified combustion permits faster load variation and fluctuation.
- In the case of pulverised coal combustion, hot air can be used for heating the coal as well as for transporting the pulverised coal to burners.
- This being a non-pressure part will not warrant shut-down of unit? due to corrosion of heat transfer surface which is inherent with lowering of flue gas temperature.

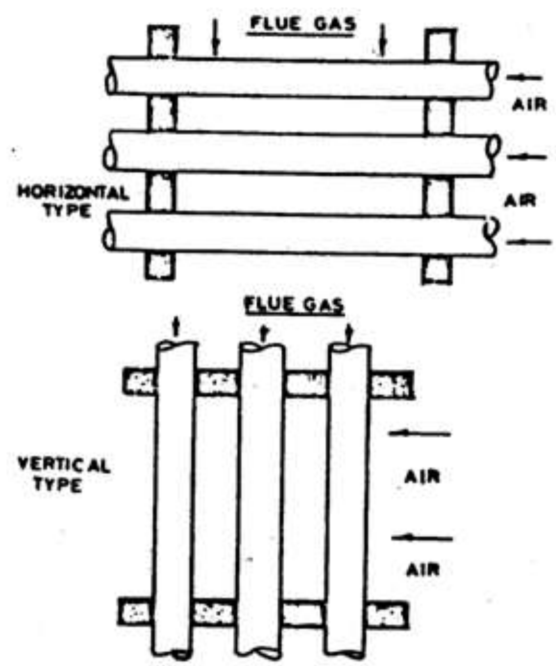
Type of Airheaters Airheaters can be classified based on their operating principle.

In Recuperative type, heating medium is on one side and air is on the other side of tube or plate and heat transfer is by conduction through the material which separates the media. Due to static construction, less chances of leakage through expansion joints, access doors, casings etc.

In Regenerative type, the heating medium flows through a closely packed matrix to raise its temperature and then air is passed through the matrix to pick-up the heat Either the matrix or the hoods are rotated to achieve this and hence ,leakage through sealing arrangements at the moving surfaces is high.

Recuperative Airheaters : These type of air heaters can further be classified as:

Tubular Airheater : There are large number of steel tubes .Either gas or air may be designed to flow through the tube. Gas through the tube normally requires higher size tube and vertical flow to reduce fouling. Airheater portion at low temperature is designed normally with a shorter tube length so as to facilitate maintenance of surfaces due to corrosion and fouling. In some cases, like starting, instead of using boiler flue gases, external firing elements are used.



Tubular Airheater

Plate type Airheater These comprise of parallel plates which provide alternate passage for gas and air. This type is simple and compact compared to that of tubular type. The narrow passes between plates make the cleaning tedious but with shot cleaning method it is improved. But replacement is a major task.

Steam Air Preheater This does not utilize the heat from boiler flue gas and hence does not improve boiler efficiency. Normally this is used only during starting when flue gas temperature entering the regular airheater is low and hence further heat extraction is not possible and low temperature corrosion prevails. Condenser for this should be provided with air removal system so that any air entering with steam will not lock and prevent the operation of airheater. Air outlet temperature can be controlled easily.

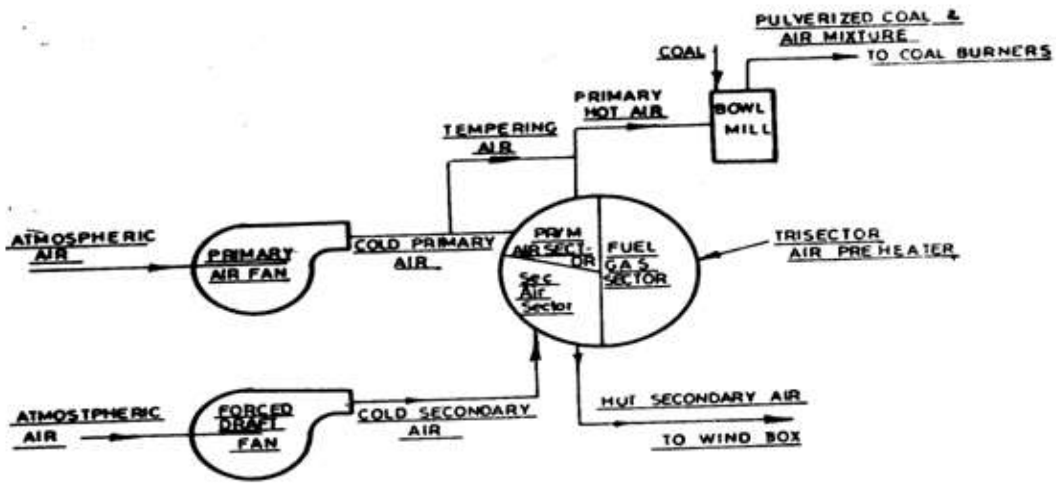
Regenerative Air Heaters These air heaters, again, can be further subdivided into different types based on their constructional features as follows.

Langsdorm type The heat transfer elements are rotated at a constant speed and they pass alternatively through gas and air passes. The axis of rotation may be horizontal or vertical. The drive is normally electrical operated through reduction gear with compressed air motor as stand-by. The plates forming the elements (matrix) may be varied in spacing and thickness and cold ends are made of special corrosion resistance alloy such as corten or enameled to achieve corrosion resistance. This type is very compact and bends easily for ducting arrangement. Effective cleaning of heater - transfer surface by soot blowing is possible.

Rothemuhle type This type is the same as the Langsdorm except that the matrix element is stationary and the air / gas hoods rotate. Again axis of rotation may be horizontal or vertical.

Tri sector Air Heater As the name implies, this design has three sectors- One for flue gas, one for primary(air used for drying and transport of coal through mill to the burner), one for secondary air (additional air for combustion around the burners). This helps in avoiding wastage of heat pick up by air due to primary air flow and also helps in selecting different temperatures for primary air and secondary air. The housing of the trisector preheater is arranged to permit counter flow of hot flue gases. A sealing system separates the flue gas, the primary air and the secondary air from each other.

As the rotor revolves slowly through the three streams, the surfaces continuously absorb heat from the flue gas and release it to the incoming primary and secondary air.



Primary and Secondary Air System

Flue Gas Cleaning Equipments: The objectives of flue gas cleaning are:-

- To reduce stack emission-
- To confirm to statutory requirements
- To fulfill a moral obligation and civic responsibility.
- To reduce wear on ID fans.

The selection of emission control equipments are affected by following factors: -

- Properties of delivered coal: Amounts of sulphur, ash and other constituents will have a bearing on the type of equipment to be selected.

- Size of boiler plant: This will, of course, help to determine required capacity of emission control equipment and, in some cases type of equipment.

- Type of Firing: This will influence the concentrations and sizes of pollutants that reach the stack.

- Pollution control regulations are also to be considered.

Classification: The "mechanical" and "electrostatic" precipitators have seen the most service in coal-dust removal; however, "filters" and "scrubbers" now see increasing service as concern over SO_2 grows. The two important mechanical types of precipitators are:

- Gravity and momentum separation equipment.
- Centrifugal separators.

Electrostatic Precipitator

When coal is fired in the boiler, about 80% of ash released is carried along with the flue gas. It is necessary to precipitate the dust from the flue gas before releasing in atmosphere, hence precipitators are used. The additional advantage obtained is that the wear of the ID fan blades are reduced due to precipitation of dust, resulting in reduced maintenance work in ID fan. The electrostatic precipitator is efficient in precipitation of particles from submicron to large sizes of particles and hence they are preferred to mechanical precipitators. The efficiency of modem ESP's is of the order of 99.9%.'

Construction: The electrostatic precipitator consists of a large chamber in which collecting and discharge electrodes are suspended. The collecting electrodes are made out of steel plates and discharge electrodes are made of thin wire (2.5mm dia) wound to a helical form. The discharges electrodes are kept in between collecting electrodes are arranged alternatively.

At the inlet of the chambers, gas distributor screens are provided which are nothing but perforated steel plate. These are for uniform gas distribution across the section of the chamber.

The collecting plates at its power portion contains shock bars over which rapping is provided for discharge or emitting electrodes to dislodge ash from the wire.

Furnace Safeguard Supervisory System (FSSS)

Basic Concept of operation of FSSS

FSSS is an independent and discreet digital logic system which provides safety and protection during starting, shut down, low load and emergency conditions. It does not take part in the regular station operation as in the case with combustion control which sends out continuous analogue signal to maintain combustion rate at optimum value to match the demand of the boiler.

In the present BHEL designed boilers, tangential firing system has been adopted in which air and fuel are admitted on elevation basis located at the corners of the furnace and arranged to fire tangentially at the centre of the furnace. Igniters are provided at appropriate locations to fire directly across the line of admission of the oil stream. Optical flame scanners are strategically located at different levels. Fuel air and auxiliary air dampers are continuously modulated to distribute the incoming air for optimum firing conditions. Wide angle flame scanners monitor the flame in the furnace as single entity.

Functions of FSSS

- Furnace Purge Supervision: Which has interlocks for scanners purge airflow, drum level and all fuel.
- Secondary air damper control: To automatically maintain wind box furnace differential, regulate air to the fuel compartment and control the secondary air dampers.
- Ignitor control supervision : Which has interlocks for ignitor flame, furnace purge, ignition fuel pressure and ignitor tip valve position.
- Heavy Oil Control and Supervision: It has remote and manual start/stop. It includes interlocks for heavy oil pressure and temperature, oil gun valve

positions, ignitor energy atomising differential and local maintenance switches.

- Mill and Feed control and Supervision: It has automatic operation from a single operator, start-stop switch for each mill. Individual switches are also provided for the operator to control each mill. It also includes interlocks for ignition energy, primary air-shut off gate position, mill outlet temperature and proper mill start-stop procedure.

- Flame scanners intelligence and checking: Includes automatic checking of each scanner, scanner counting networks and scanner cabinet.

- Overall boiler flame failure protection: It is used during light up and low load operation.

- Boiler trip protection which shuts down all fuel in the following events :
  - Both emergency trip buttons pushed
  - Loss of all fuel
  - Turbine trip
  - Air flow less than a minimum preset value (during start-up only)
  - Tripping of FD/ID Fans.
  - Loss of flame.

3. Main Turbine & Auxiliaries

Steam Turbine Theory

Steam turbine as a Prime mover: The steam turbine is better than prime movers, both thermodynamically and mechanically. In the turbine, the steam can be expanded down to a lower back pressure, thereby making available a greater heat drop. If a reciprocating steam engine were to expand the steam down to a back pressure of the order of an inch or two of mercury, the low pressure cylinders would have to be very large to deal with the large volume of steam resulting from these pressures. This would be impractical and uneconomical. Also, the internal efficiency of the turbine is high so it is able to convert a high proportion of this relatively large heat drop into mechanical work.

From a mechanical point of view, the turbine is ideal, because the propelling force is applied directly to the rotating element of the machine. But, in case of reciprocating engine, transmitted through a system of connecting links which are necessary to transform a reciprocating motion into a rotary motion.

If the load on a turbine is kept constant, the torque developed at the coupling is also constant. A generator at a steady load offers a constant torque. Therefore, a turbine is suitable for driving a generator, particularly as they are both high speed machines.

A further advantage of the turbine is the absence of internal lubrication. This means that the exhaust steam is not contaminated with oil vapor and can be condensed and fed back to the boilers without passing through filters. This saves a lot of lubricating oil as well.

Most importantly, a turbine can develop many times the power compared to a reciprocating engine whether steam or oil.

Operating Principles

Steam turbines can have many stages. The rotor is a rotating shaft that carries the moving blades on the outer edges of either discs or drums. The blades rotate as the rotor revolves. The rotor of a large steam turbine consists of high, intermediate, and low-pressure sections. In a multiple-stage turbine, steam at a high pressure and high temperature enters the first row of fixed blades or nozzles through an inlet valve(s). As the steam passes through the fixed blades or nozzles it expands and its velocity increases. The high-velocity jet of steam strikes the first set of moving blades. The kinetic energy of the steam changes into mechanical energy, causing the shaft to rotate. The steam then enters the next set of fixed blades and strikes the next row of moving blades.

As the steam flows through the turbine, its pressure and temperature decreases, while its volume increases. The decrease in pressure and temperature occurs as the steam transmits energy to the shaft and performs work. After passing through the last turbine stage, the steam exhausts into the condenser or process steam system.

An impulse turbine uses the impact force of the steam jet on the blades to turn the shaft. Steam expands as it passes through the nozzles, where its pressure drops and its velocity increases. As the steam flows through the moving blades, its pressure remains the same, but its velocity decreases. The steam does not expand as it flows through the moving blades. A simple impulse turbine is not very efficient because it does not fully use the velocity of the steam. Many impulse turbines (velocity-compounded turbine) have extra sets of moving blades which make use of the high velocity steam leaving the first set of moving blades.

Another type of impulse turbine is a pressure-compounded turbine. It consists of two or more simple impulse stages contained in one casing. The casing contains diaphragms that connect to nozzles. The nozzles make efficient use of the steam pressure that remains after the steam flows through the previous stage. The pressure drops in each stage as steam expands through the nozzles.

A reaction turbine uses the "kickback" force of the steam as it leaves the moving blades and fixed blades have the same shape and act like nozzles. Thus, steam expands, loses pressure and increases in velocity as it passes through both sets of blades. All reaction turbines are pressure-compounded turbines.

Many large turbines use both impulse and reaction blading. These combination turbines usually have impulse blading at the high-pressure end, and reaction blading at the low- pressure end. The blade length and size increases throughout the turbine to use the expanding steam efficiently. Blade rows require seals to prevent steam leakage where the pressure drops. Seals for impulse blading are located between the rotor the diaphragm to stop leakage past the nozzle. Seals for reaction blading are located at the tips of both the fixed and moving blades.

Classification of Turbines

Steam turbines may be classified into different categories :-

According to the number of pressure stages:

- Single-stage turbines with one or more velocity stages usually of small power capacities, these turbines are mostly used for driving centrifugal compressors, blowers and other similar machinery.
- Multistage impulse and reaction turbines; they are made in a wide range of power capacities varying from small to large.

According to the direction of steam flow:

- Axial turbines in which the steam flows in a direction parallel to the axis of the turbine;
- Radial turbines in which the steam flows in a direction perpendicular to the axis of the turbine with one or more low pressure stages in such turbines being axial.

According to the method of governing:

- Turbines with throttle governing in which fresh steam enters through one or more (depending on the power developed) simultaneously operated throttle valves.
- Turbines with nozzle governing in which fresh steam enters through two or more consecutively opening regulators.
- Turbine with bypass governing in which steam, besides being fed to the first stage is also directly led to one, two or even three intermediate stages of the turbine.

According to the principle of action of steam:

- Impulse turbines.
- Axial reaction turbines.
- Radial reaction turbines with stationary guide blades.
- Radial reaction turbines without any stationary blades.

According to the steam conditions at inlet to turbines:

- Low-pressure turbines, using steam at pressure of 1.2 to 2 ata.
- Medium -pressure turbines, using steam at pressure of upto. 40 ata.
- High-pressure turbines, utilising steam at pressure above 40 ata.
- Turbines of very high pressures, utilising steam at pressures of 170 ata and higher and temperature of 535 deg. C and higher.

- Turbines of supercritical pressures, using steam at pressure of 255 ata and above.

According to their usage in industry:

- Turbines with constant speed of rotation primarily used for driving alternators:
- Steam turbines with variable speed meant for driving turbo-blowers, air circulators, pumps etc.
- Turbines with variable speed: Turbines of this type are usually employed in steamers, ships and railway locomotives (turbo-locomotives).
- All these different types of turbines described above depending on their speed of rotation are either coupled directly or through a reduction gear to the driven machine.

Turbine Components

The Main Turbine

The turbine installed is of condensing-tandom -compound, three cylinder,- horizontal, disc and diaphragm, reheat type with nozzle governing and regenerative system of feed water heating and is coupled directly with A. C. Generator. It is a 200/210 MW turbine.

The various main components of the turbine are described in the following sections.

Rotors

High Pressure Rotor: The HP rotor is machined from a single Cr-Mo-V steel forging with integral discs. The rotor forging is thermally stabilised to prevent abnormal defection/ The blades are attached to their respective wheels by "T" root fastening. In all the moving wheels, balancing holes are machined to reduce the pressure difference across them, which results in reduction of axial thrust. First stage has integral shrouds while other rows have shroudings, rivetted to the blades are periphery. The number of blades connected by a single strip of shrouding is called a blade packet.

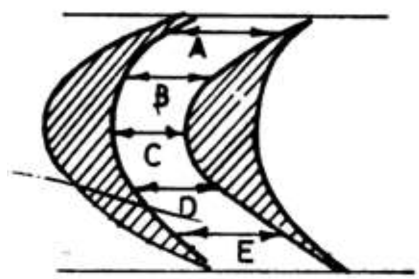
Intermediate Pressure Rotor: The IP rotor has seven discs integrally forged with rotor while last four discs are shrunk fit. The shaft is made of high creep resisting Cr-Mo-V steel forging while the shrunk fit disc are machined from high strength nickel steel forgings. The blades on the integral disc are secured by "T" root fastenings while on shrunk fit disc by 'fork root' fastening. Except the last two wheels, all other wheels have shroundings rivetted at the tip of the blades. To adjust the frequency of the moving blades, lashing wires have been provided in some stages.

Low Pressure Rotor: The LP rotor consists of shrunk fit discs a shaft. The shaft is a forging of Cr- Mo-V steel while the discs are of high strength nickel steel forgings. Blades are secured to the respective discs by rivetted fork root fastening. In all the stages lashing wires are providing to adjust the frequency of blades. In the last two rows satellite strips are provided at the leading edges of the blades to protect them against wet steam erosion.

Blades

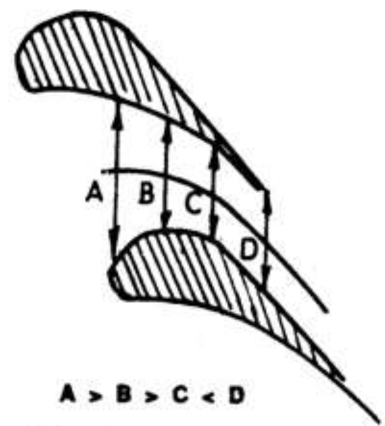
Blades are single most costly element of turbine. Blades fitted in the stationary part are called guide blades or nozzles and those fitted in the rotor are called moving or working blades. The following are three main types of blades:

- Cylindrical (or constant profile) blade (refer fig A)
- Tapered cylindrical (tapered but similar profile).
- Twisted and varying profile blades. (refer fig B)



A = B = C = D = E

(A) Impulse Blade



A > B > C < D

(B) Reaction Blade

Blades have three main parts (a) Aerofoil: It is working part of blade and is one of the types described above, (b) Root: It is portion of the blade which is held with the disc, drum or turbine casing and (c) Shrouds.

Three types of root arrangements are commonly used. They are (1) T-roots: for small blades; (2) Fir Tree or serrated roots - for longer blades; (3) Fork and Pin root: for longer blades shrunk on disc type rotors.

Shrouds can be either riveted by tannon to main blade or it can be integrally machined with the blade. Now-a-days trend is towards integral shroud for shorter) lades and shrunk filting for larger blades. Some times lacing wires are also used to dampen the vibration and to match frequencies in the longer blades. Since in the reaction type machine the pressure drop also occurs across the moving blades it is necessary to provide effective sealing at the blade tips. This must be done to prevent leakage steam past the shrouding of the wheel and consequent loss efficiency particularly at the high-pressure end of the machine.

Now-a-days trend is for precision forged blades for long twisted blades, as it saves valuable machining time, resulting in reduction in cost.

Liners and Diaphragms: In reaction turbines, guide blades are directly carried in the casings and hence liners and diaphragms are not generally used, In impulse turbines, most of the pressure drop of a stage takes in guide blades resulting in higher deflection of guide blades. Additional bending strength to guide blades is provided by diaphragms, Welded diaphragms are used in higher temperature zones while cast diaphragms are used in low temperature zones. Two to four diaphragms are housed in a liner, which in turn is housed in the turbine casing, provide cham ber for bleed steam and at the same time save casing from higher speed steam erosion. With the use of liners, machining of casing also becomes much simpler.

Sealing Glands

To eliminate the possibility of steam leakage to atmosphere from the inlet and exhaust ends of the cylinder, labyrinth glands of the radial clearance type are provided which provide a trouble free frictionless sealing.

Each gland sealing consists of a number of sealing rings divided into segments, each segment is backed by two flat springs. The sealing rings are housed in grooves machined in gland bodies which are in turn housed in the turbine casing, or bolted to the casing at ends.

Steam is supplied to the sealing chamber at 1.03 to 1.05 Kg/sq.cm abs and at temperature 130 deg.C To 150 deg.C from the header, where the pressure is maintained constant with the help of an electronic regulator. Air steam mixture from the last sealing chamber is sucked out with the help of a special steam ejector to gland steam cooler.

Provision has been made to supply live steam at the front sealing of H.P. and I.P. rotor to control the differential expansion, when rotor goes under contraction during a trip or sharp load reduction.

Emergency Stop Valves and Control Valves

Turbine is equipped with emergency stop valves to cut off steam supply and with control valves regulate steam supply. Emergency stop valves (ESV) are provided in the mainstream line ad Interceptor valves (IV) are provided in the hot reheat line.

Emergency stop valves are actuated by servomotor controlled by the protection system. ESV remains either fully open or fully close.
Control valves are actuated by the governing system through servomotors to regulate steam supply as required by the load.
Valves are either single seat type or double seat type. Single seat type valves are preferred though these required higher force for opening or closing.

Couplings

Since the shaft (rotor) is made in small parts due to forging limitations and other technological and economic reasons, the couplings are required between any two rotors. The coupling permits angular misalignment, transmits axial thrust and ensures axial location. The couplings are either rigid or semi flexible The former neither permits angular nor lateral deflection while the later permits only angular defection Number of critical speeds depend upon the modes of vibration and hence the type of coupling provided between rotors. Generally in 200/210 MW turbines, coupling between HPT and IPT is of rigid type and between IPT and LPT is of semi-flexible lens type.

Bearings

Journal bearings are manufactured in two halves and usually consist bearing body faced with anti-friction tin based habiting to decrease coefficient of friction. Bearing body match with adjustable seating assembly in the pedestal. Bearings are usually forced lubricated and have provision for admission of jacking oil.

The thrust bearing is normally Mitchell type and is usually combined with a journal bearing, housed in spherically machined steel shell. The bearing between the HP and IP rotors is of this type; while the rest are journal bearings. Earlier each rotor used to have its own set of bearings, Now with the popularity of rigid coupling between rotors, it is possible to use only one bearing between two rotors. This arrangement will lead to more flexible rotors (lower critical speed), for the same rotor design because span between bearings increases. With reduction in number of bearings, length of turbine gets reduced resulting in considerable saving in capital cost.

Barring Gear

The barring gear is mounted on the L.P. rear bearing cover to mesh with spur gear on L.P. rotor rear coupling. The primary function of the barring gear is to rotate the turbo-generator rotors slowly and continuously during start-up and shut down periods when changes in rotor temperature occur.

When a turbine is shut down, cooling of its inner elements continues for many hours. If the rotor is allowed to remain stand still during this cooling period, distortion of rotor begins almost immediately. This distortion is caused by flow of hot vapours to the upper part of casings, resulting in upper half of turbine beings at a higher temperature, than lower half. Hence to eliminate the possibility of distortion during shut-down, barring gear is used to keep the rotor revolving until the temperature change has stopped and casings have become cool. This also results in maintenance of minimum inter stage sealing clearances with higher operating efficiency.

The same phenomena is also observed during starting of the turbine, when steam is supplied to the sealings to create the vacuum. If the rotor is stationary, there would be non-uniform heating of the rotor which will result in distortion of rotors. The barring gear during starting of turbine, would slowly rotate the turbine- generator rotor, and thereby resulting in the uniform heating of rotor. Thus any distortion on the rotor would be avoided. During starting period operation of the barring gear eliminates the necessity of 'breaking away' the turbine generator rotors from stand still and thereby provides for a more uniform, smooth and controlled starting.

Arrangement of Turbine Auxiliaries

The turbine cycle can be viewed in the form of different systems as given below:-

Vacuum System This comprises of

- Condenser - 2 per 200MW unit at the exhaust of LP turbine.
- Ejectors **-** One starting and two main ejectors connected to the condenser located near the turbine.
- C.W. Pumps : Normally two per unit of 50% capacity.

Condensate System This contains the following :

- Condensate Pumps - 3 per unit of 50% capacity each located near the condenser hot well.
- LP Heaters - Normally 4 in number with no. 1 located at the upper part of the condenser and nos. 2,3 & 4 around 4m level.
- Deaerator - One per unit located around 18 'M' level in CD bay.

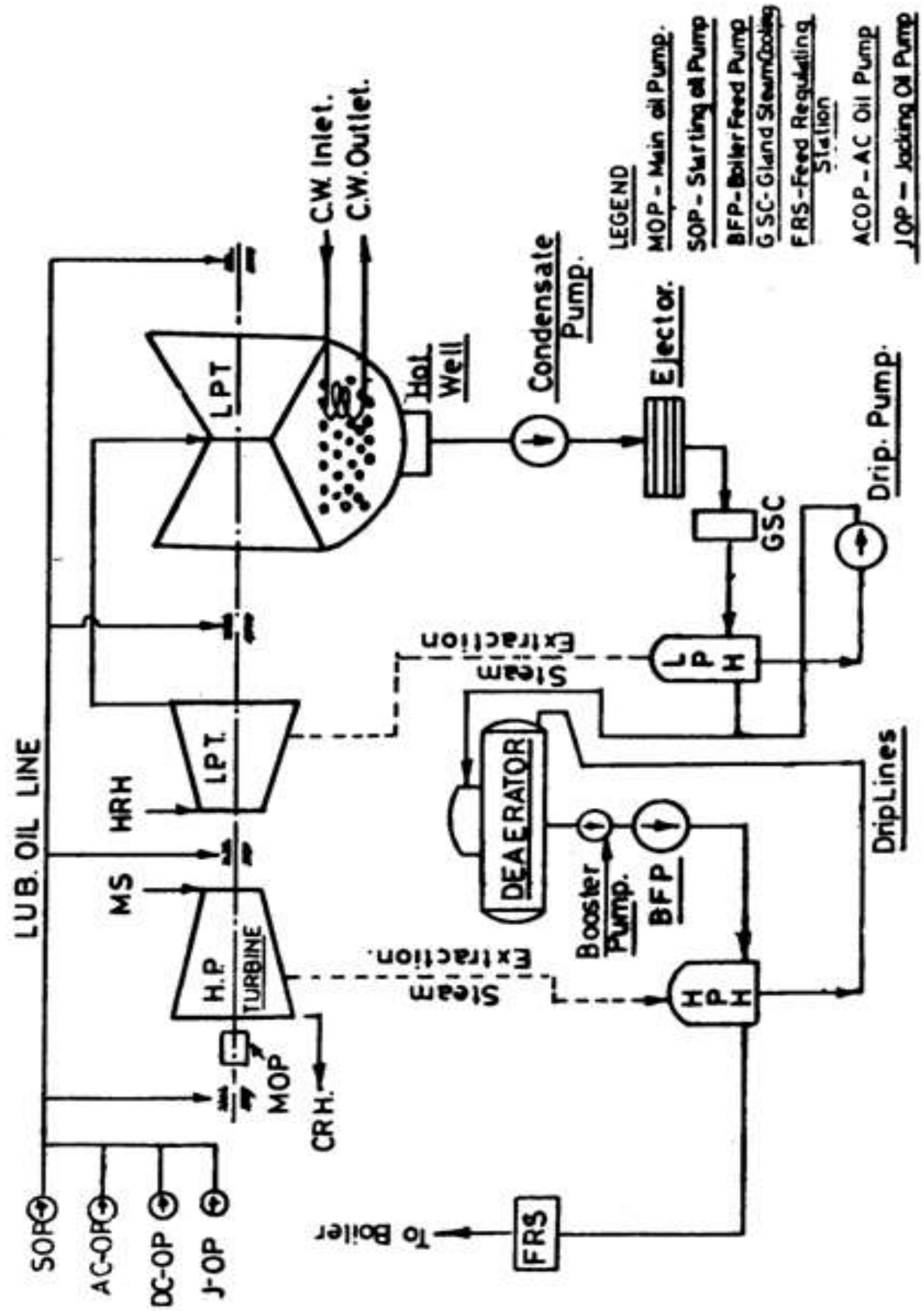
Feed Water System The main equipments coming under this system are:

- Boiler Feed Pump : Three per unit of 50% capacity each located in the '0' meter level in the TG bay.
- High Pressure Heaters: Normally three in number and are situated in the TG bay.

Drip Pumps: Generally two in number of 100% capacity each situated beneath the LP heaters.

Turbine Lub Oil System This consists of Main Oil Pump (MOP) Starting Oil Pump (SOP), AC standby oil pumps and emergency DC oil pump and Jacking Oil Pump (JOP) (one each per unit).

Auxiliary Steam System The main 16 ata header runs parallel to BC bay at the level of around 18 'M'.


LUB. OIL LINE
MS
HRH
H.P. TURBINE
LPT.
LPT
MOP
CRH.
SOP
AC-OP
DC-OP
J-OP
FRS
To Boiler
Steam Extraction.
Steam Extraction
HPH
LPH
DEAERATOR
Booster Pump.
BFP
DripLines
Drip. Pump.
GSC
Ejector.
Condensate Pump.
Hot Well
C.W. Inlet.
C.W. Outlet.
LEGEND
MOP - Main oil Pump.
SOP - Starting oil Pump
BFP - Boiler Feed Pump
GSC - Gland Steam Cooler
FRS - Feed Regulating Station
ACOP - AC Oil Pump
JOP — Jacking Oil Pump

Vacuum & Condensate System

VACUUM SYSTEM

The first system of recirculating process is the vacuum system. The equipment under this system, strive to maximize the work done of turbine by maintaining the rated vacuum limits.

Condenser

There are two surface type condensers with two pass arrangement, entered to the two exhausters of the L.P. turbine. Cooling water pumped into each condenser by a vertical C.W. pump through the inlet pipe. Water enters the inlet chamber of the front water box, passes horizontally through the brass tubes to the water box at the other end, takes a turn, passes through the upper cluster of tubes and reaches the outlet chamber in the front water box. From these, cooling water leaves the condenser through the outlet pipe and discharge into the discharge duct.

Steam exhausted from the L.P. turbine washing the outside of the condenser tubes losses its latent heat to the cooling water and is connected with water in the steam side of the condenser. This condensate collects in the hot well, welded to the bottom of the condensers.

Ejectors

Ejector evacuates air and other non-condensing gases from the condensers and thus maintain the vacuum in the condensers. There are two 100% capacity ejectors of the steam eject type.
This is a three stage ejector using steam from the deaerator with 11 ata header as the working medium. The ejector has three compartments. Steam is supplied generally at a pressure of 4.5 to 5 Kg/sq.cm. to the three nozzles in the three compartments. Steam expands in the nozzle thus giving a high velocity eject which creates a low pressure zone in the throat of the eject. Since the nozzle box of the ejector is connected to the air pipe from the condenser, the air and pressure zone. The working steam which has expanded in volume comes into contact with the cluster of tube bundles thru' which condensate is flowing and gets condensed thus further aiding the formation of vacuum. The non-condensing gases of air are further sucked with the next stage of the ejector by the action of the second nozzle. The

process repeats itself in the third stage also and finally the steam air mixture is exhausted into the atmosphere through the outlet.

There is another single stage starting ejector which is used for initial pulling of vacuum upto 500mm of Hg. It consists of nozzle through which the working steam expands: the throat of the nozzle is connected to the air pipe from the condenser.

C.W. Pumps

Two pumps, called circulating water pumps, are provided for each unit which supply the cooling water to the condensers .

These pumps are normally vertical, wet-pit, mixed flow type, designed for continuous heavy duty; suitable for water drawn through an open gravity intake channel terminating in twin-closed ducts running parallel to the main building.

The suction bowl/eye is provided with streamlined guide vanes, whose function is to prevent pre-whirl and impart hydraulically correct flow to the liquid. The propeller, in turn, imparts motion to the fluid. The purpose of the discharge bowl, provided with streamlined diffuser vanes, is to direct the flow of water into the discharge column.

Gland steam & Gland steam Cooler

Steam from deaerator or from auxiliary steam header is supplied to the end seal of the H.P. rotor and L.P. rotor generally at a pressure of 1.01 to 1.03 atm. abs. so as to prevent ingress of atmospheric air into the turbine thru' the end clearances. This steam supplied to the end seals is extracted by the gland steam cooler by the action of single stage steam ejector.

CONDENSATE SYSTEM

Condensate Pumps

The function of these pumps is to pump out the condensate to the deaerator through ejectors, gland steam cooler, and L.P. heaters. These pumps have four stages and since the suction is at a negative pressure, special arrangements have been made for providing sealing.

L.P. Heaters

Turbine has been provided with non-controlled extractions which are utilised for heating the condensate, from turbine bleed steam. There are 4 low pressure heaters in which the last four extractions are used.

L.P. Heater -1 has two parts LPH-1A and LPH-1B located in the upper parts of condenser A and condenser B respectively. These are of horizontal type with shell and tube construction. L.P.H. 2,3 and 4 are of similar construction and they are mounted in a row at 5M level. The condensate flows in the "U" tubes in four passes and extraction steam washes the outside of the tubes. Condensate passes thru' these four L.P. heaters in succession. These heaters are equipped with necessary safety valves.

Deaerator

Certain gases, specially oxygen, carbon-di-oxide and ammonia, dissolved in water are corrosive for metals, particularly at elevated temperatures. Therefore, these dissolved gases should be removed from the feed water by a deaerator by mechanical means. Particularly the unit must reduce the oxygen content of the feed water to as low as is possible or desirable, depending upon the individual circumstances, residual oxygen content in condensate at the outlet of deaerating plant usually specified is 0.005/litre or less.

Principle of Deaeration: The principle of de-aeration is based on following two laws.

- Henrys law: The mass of gas with definite mass of liquid will dissolve at a given temperature and is directly proportional to the partial pressure of the gas in contact with the liquid. This holds within close limits for any gas, which does not unite chemically with the solvent.
- Solubility Law: Solubility of gases decreases with increase m solution temperature and/or decrease in pressure.

The continuous movement of the molecules of the gas and solvent results in molecules migrating across the liquid surface and when the migration to and from the liquid is equal, equilibrium is reached. Reaching equilibrium may be hastened by deaerating the size of water particles thereby reducing the distance to be travelled by gas molecules and increasing the surface of mass ratio and by agitation, which brings internal sections of the liquid to the surface.

A constant pressure deaerator, pegged at 7 Kg/sq.cm. is envisaged in turbine regenerative cycle to provide properly deaerate feed water for boiler, limiting gases (mainly oxygen) to 0.005 CC/liter. It is a direct contact type heater combined with feed storage tank of adequate capacity. The heating steam is normally supplied from turbine extractions but during starting and low load operation the steam is supplied from auxiliary source.
The de-aerator comprises of two chambers: De-aerating column and feed storage tank.

De-aerating column is a spray cum tray type cylindrical vessel of horizontal construction with dished ends welded to it. The tray stack is designed to ensure maximum contact time as well as optimum scrubbing of condensate to achieve efficient de-aeration. The de-aeration column is mounted on the feed storage tank which in turn is supported on rollers at the two ends and a fixed support at the centre. The feed storage tank is fabricated from boiler quality steel plates. Manholes are provided on de-aerating column as well as on feed storage tank for inspection and maintenance.

The condensate is admitted at the top of the deaerating column flows downwards through the spray valves and trays. The trays are designed to expose to the maximum water surfaces for efficient scrubbing to affect the liberation of the associated gases- steam enters from the underneath of the trays and flows in counter direction of condensate. While flowing upwards through the trays, scrubbing and heating is done. Thus the liberated gases move upwards along with the steam. Steam gets condensed above the trays and in turn heats the condensate. Liberated gases escapes to atmosphere from the orifice opening meant for it. This opening is provided with a number of deflectors to minimise the loss of steam.
Deaerator is provided with the following fittings.

- Tubular type gauge glass.
- High level alarm switch.
- Low level alarm switch.
- Pressure gauge.
- Straight thermometers with pockets.
- Safety valve
- Isolating valves for steam pipes.

Feed Water & Auxiliary Steam System

FEED WATER SYSTEM

Boiler Feed Pumps

This pump is horizontal and of barrel design driven by an Electric motor through a hydraulic coupling. All the bearings of pump and motor are forced lubricated by a suitable oil lubricating system with adequate protection to trip the pump if the lubrication oil pressure falls below a preset value.

The feed pump consists of pump barrel, into which is mounted the inside stator together with rotor. The hydraulic part is enclosed by the high pressure cover along with the balancing device. The suction side of the barrel and the space in the high pressure cover behind the balancing device are enclosed by the low pressure covers along with the stuffing box casings. The brackets of the radial bearing of the suction side and radial and thrust bearing of the discharge side are fixed to the low pressure covers. The entire pumps are mounted on a foundation frame. The hydraulic coupling and two claw coupling with coupling guards are also delivered along with the pump. Water cooling and oil lubricating are provided with their accessories.

Mechanical Seal The use of mechanical seal reduces the loses of feed water in the stuffing box to a minimum and working ability of the feed pump increases. Cooling of stuffing box space should be perfect by the use of mechanical seal. Cooling is carried out by the circulation of water between the stuffing box space and the cooler. Even after stopping the pump, stuffing box cooling should be continued as its cooling circuit is different from the seal cooler. Coolers are designed to keep the stuffing box space temperature below 80 deg.C.

The water with the given operating temperature should flow continuously to the pump under a certain minimum pressure. It passes through the suction branch into the intake spiral and from there is directed to the first impeller. After leaving the impeller it passes through the distributing passages of the diffuser and thereby gets a certain pressure rise and at the same time it flows over to the guide vanes to the inlet of the next impeller. This will repeat from one stage to the other till it passes through the last impeller and the end diffuser. Thus the feed water reaching into the discharge space develops the necessary operating pressure.

Balancing Device A small portion of the feed water in the order of about 10% which is not calculated to the guaranteed delivery capacity is taken of 'f from the space behind the last impeller for the operation of the automatic balancing device to balance the hydraulic axial thrust of the pum p rotor. The purpose of the balancing device is to take up thrust pressure in a similar way as the thrust hearing. It is evident from the function of the balancing device that behind the balancing disc the pressure must not rise, otherwise the hydraulic equibilirum will be broken and therefore equalizing piping must have a sufficient flow capacity. A pressure gauge connection is given for the control of pressure in the equalising piping. For safe operating of the balancing device, the pressure value on this pressure gauge should be 0.5 to 2 atm, higher than the intake suction branch pressure. With the pressure rise in the balancing space by 5 atm. above the suction pressure it is necessary to trip the pump in order to find out the cause of defect and to rectify it.

Lubricating System All the bearings of boiler feed pump, pump motor and hydraulic coupling, are force lubricated. The feed pump consists of two radial sleeve bearings and one thrust bearing. The thrust bearing is located at the free-end of the pump. The feed pump driving motor consists of two radial sleeve bearings. Feed pump is coupled with its driving motor through hydraulic coupling which serves the purpose of controlling the speed of feed pump for maintaining a definite delivery head and quality of feed water as per requirement of the boiler. This hydraulic coupling consists of four radial bearings and two tilting pad bearings.

Booster Pump: Each boiler feed pump is provided with a booster pump in its suction line which is driven by the main motor of the boiler feed pump. One of the major damages which may occur to a B.F. pump is from cavitation or vapour bounding at the pump suction due to suction failure. Cavitation will occur when the suction pressure of the pump at the pump at the pump suction is equal or very near to the vapour pressure of the liquid to be pumped at a particular feed water temperature. By the use of a booster pump in the main pump suction line, always there will be positive suction pressure which will remove the possibility of Cavitation. Therefore all the feed pumps are provided with a main shaft driven booster pump in its suction line for obtaining a definite positive suction pressure

Turbine Driven Boiler Feed Pump

The single cylinder turbine is of the axial flow type. The live steam flows through the emergency stop valve and then through the main Control Valves (5 nos. (Nozzle governing). These valves regulate the steam supply through the turbine in accordance with load requirements. The control valves are actuated by a lift bar which is raised or lowered via a lever system by the relay cylinder mounted on the turbine casing.

The journal bearings supporting the turbine shaft are arranged in the two bearing blocks. The front end-bearing block also houses the thrust bearing, which locates the turbine shaft and takes up "the axial forces.There are 14 stages of reaction blading. The balancing piston is provided at the steam admission side to compensate the axial thrust to the maximum extent. Since the axial thrust varies with the load, the residual thrust is taken up in the thrust bearing. The leak off from the balancing piston is connected back to the turbine after 9th stage.The turbine is provided with hydraulic and electro-hydraulic governing system. A primary oil pump is used as a speed sensor for hydraulic governing and shall Probes are used as a speed sensor for electro hydraulic governing. Whenever steam is drawn from the cold reheat line or auxiliary supply, steam flow is controlled by auxiliary control valve. During this period the main control valves (4 nos.) will remain fully opened and the bypass valve across it will remain closed. (Bypass remains closed for a short period when changeover from IP steam to CRH takes place). The steam exhaust from the BFP- Turbine is connected to the main condenser and the turbine glands are sealed by gland steam.

High Pressure Heaters:

These are regenerative feed water heaters operating at high pressure and located by the side of turbine. These are generally vertical type and turbine bleed steam pipes are connected to them.

HP heaters are connected in series on feed waterside and by such arrangement, the feed water, after feed pump enters the HP heaters. The steam is supplied to these heaters form the bleed point of the turbine through motor operated valves. These heaters have a group bypass protection on the feed waterside. In the event of tube rupture in any of the HPH and the level of the condensate rising to dangerous level, the group protection device diverts automatically the feed water directly to boiler, thus bypassing all the 3 H,P. heaters. Feed water flows through the tube spirals and is heated by steam around the tubes in the shall of the heaters. These heaters are cylindrical vessels with welded dished ends and with integrated, desuperheating, condensing and sub cooling sections. The internal tube system of spirals is welded to the inlet and outlet headers. In order to facilitate assembly and disassembly, rollers at the side of the header have been provided. Both feed water and steam entries and exits are from the bottom end of the heaters. This design offers the advantage to optimise the arrangement of piping and the location of the heaters at Power Station.

Group Protection device of HP Heaters: In the event of rising of the drain condensate level in any one of the HP heater, to the emergency high level, the feed water flowing through the coils of the heaters, is diverted automatically directly to the boiler, thereby all the group of three HP heaters is bypassed from feed water side as well as from steam side.

Feed Regulating Station

To ensure security of supply, a multiple feed-water regulating valve arrangement is required. On 200 MW unit, there is a 100% regulating valve and there are two smaller regulating valves for low load conditions which can also be used for standby duty.

The essential factors in obtaining the fine degree of regulation required are the steam flow from the boiler, the feed water flow to the boiler and the water level in the boiler drum. To maintain the rate of feed-water input in correct ratio to the steam output under all conditions of loading, the system measures feed flow and steam -flow and the meter readings are balanced against each other by means of a differential linkage.

Drip/Drain System

The steam, bleed from the turbine, after condensation is termed as drip/ drain.
The drain is cascaded from H.P.-5 will go to deaerator of L.P-H.-4 depending on the shell pressure and load on the machine. The drain of L.P.H.-2 from where the drain is pumped back into the condensate line going to deaerator. The drain from L.P.H.-2 can be regulated to condenser in case the level in L.P.H.-2 rises to a predetermined level. All the L.P. Heaters drains are having manual by-pass which can be operated in case of any individual regulator fail. The drain from L.P.H.-l is only connected to the condenser by U-tube water seal.

Drip Pumps: Two numbers of sectional multistage centrifugal horizontal pumps per unit are provided. One will be running and the other is stand-by (100% standby).These-are especially suited for the purpose of pumping from the space of high vacuum. Condensate drip from LP heater No. 2 (which is under vacuum) is pumped again to main condensate line in between LP heaters.

AUXILIARY STEAM SYSTEM

For a 210 MW Thermal Power Unit using coal as basic fuel, auxiliary steam is one of t h e important systems. The current practice is to have two different headers:-

- Turbine Auxiliary Steam Header and
- Boiler Auxiliary Header

Steam for turbine auxiliary steam header is normally taken from extraction lines depending on load on the turbine. Under normal conditions, steam comes from 5th extraction line. But whenever pressure at 5th extraction line drops, supply of steam is automatically changes from 5th to 6th extraction line. Steam thus available is taken to turbine auxiliary steam header where steam pressure can vary within a narrow range. From this header steam is supplied for the following purposes:-

- To LP Heater No.4 through a pressure reducing cum control valve for preheating condensate going to the deaerator at low loads.
- To deaerator as pegging steam through a control station-maintaining constant downsteam pressure at 7 ata. One additional tapping is made in this line after control valve for Deaerator Storage tank heating.

Steam from deaerator is supplied at 16 ata to the following systems:

- Turbine gland sealing
- Main air ejector
- Starting air ejectors
- Gland steam cooler ejector

One additional provision for steam supply is generally made from the main steam line after the final superheater. The line is connected with the veriable pressure auxiliary steam header by a pressure reducing - cum - desuperheating station wherefrom steam can directly be taken to turbine gland sealing, main ejector, starting ejector, etc. This line after PRDS is connected by a spring loaded non-return valve which opens out and allows steam only from the PRDS, whenever steam pressure in the variable steam header mentioned above drops below 10kg/cm2.

Steam from Boiler Auxiliary steam header is taken from the primary superheater inlet box and pressure reduced through two pressure reducing stations in series. Steam from this header does the following work:-

- Burner atomising, cleaning scavanging etc.
- Fuel oil system heating including fuel oil storage tank, suction/delivery pipelines, fuel oil heaters, burners ring main header, recirculation and drain lines, burner pump casing, unloading from fuel oil tanker, wagon etc.
- Interconnection to other boiler are generally made from this header.

Turbine Lubricating Oil System

Introduction

The recommended working medium for governing and lubrication system of the turbine is the MO BIL DTE oil medium or turbine oil-14 OF INDIAN OIL COMPANY.

Oil Specification

• Specific gravity at 50 ^{0}C	0.852
• Kinematic vicosity at 50 ^{0}C	28 centistokes
• Nutralisation number	0.2
• Flash Point	201^{0}C (min^m)
• Pour Point	-6.6^{0}C (max^m)
• Ash percentage by weight	0.01%
• Mechanical impurities	Nil

Main Oil Pump

This pump is mounted in the front bearing pedestal. It is coupled with turbine rotor through a gear coupling. When the turbine is running at normal speed i.e 3000 rpm or the turbine speed is more than 2800 rpm, then the desired quantity of oil to the governing system at 20 kg/cm^2 (gauge) and to the lubrication system at 1 kg/cm^2 (gauge) is supplied by this oil pump. The oil to the lubrication system at the level of turbine axis is supplied through two injectors arranged in series. First injector develops suction pressure for the main oil pump and second injector develops a pressure of3kg/cm^2 (gauge) before the coolers. After the oil coolers, the pressure is I kg/cm^2 (gauge) which goes to lubrication system.

Starting Oil Pump

It is a multi stage centrifugal oil pump driven by A.C electric motor. Starting oil pump is provided for meeting the requirement of oil of the turbo-set during starting and stopping. It also serves as standby to main centrifugal oil pump. In starting or when the turbine is running at speed lower than 2800 rpm, it supplies oil to governing system as well as to the lubrication system. For hydraulic testing of governing system, oil pipe lines and tightness of flanges joints of oil system this pump is driven by another A.C. electric motor at 1500 rpm and develops a pressure of 41kg/ cm^2

Stand-by Oil Pump

This is a centrifugal pump driven by an A.C. electric motor, this runs for 10 minutes in the beginning to remove air from the governing system and fill the oil system with the oil. This pump automatically takes over under interlock action whenever the oil pressure in lubrication system falls to 0.6 kg/cm^2 (gauge). Thus, this pump can meet the requirement of lubrication system under emergency conditions.

Emergency Oil Pump

This is a centrifugal pump, driven by D.C. electric motor. This pump has been foreseen as a back-up protection to A.C. driven standby oil pump. This automatically cuts in whenever there is failure of A.C. supply at power station and or the pressure in the lubrication system falls to O kg/cm^2 (gauge). This pump can meet the lubrication system requirement under the conditions mentioned above.

Jacking Oil Pump

This pump enable the main bearing of the complete rotor assembly to be raised or floated in the bearing during turbine generator start up and during shut down, thus preventing damage to the bearings when shaft speeds are too low for hydrodynamic lubrication to take place. This jacking oil pump takes the suction from the main oil tank and delivers a pressure of 120kg/cm^2 for lifting of rotor. The drain from the bearings is connected back to the oil tank only.

Oil Coolers

The oil of the lubrication and the governing system is cooled in the oil coolers. The cooling medium for these coolers is circulating water. The pressure of the cooling water is kept lower than that of oil to avoid its mixing with oil in the event of tube rupture.

Five oil coolers have been foreseen, out of which four are for continuous operation and one remains as standby, provided the cooling water temperature is not more than 36°C. The oil coolers are in parallel for maintenance purposes, the oil and cooling water supply to any one of the oil coolers may be cut off.

4. Generator and Auxiliaries

GENERATOR FUNDAMENTALS

Working Principle

The A.C. Generator or alternator is based upon the principle of electromagnetic induction and consists generally of a stationary part called stator and a rotating part called rotor. The stator housed the armature windings. The rotor houses the field windings. D.C. voltage is applied to the field windings through slip rings. When the rotor is rotated, the lines of magnetic flux (viz magnetic field) cut through the stator windings. This induces an electromagnetic force (e.m.f.) in the stator windings. The magnitude of this e.m.f. is given by the following expression.

E	=	4.44 /O FN volts
0	=	Strength of magnetic field in webers.
F	=	Frequency in cycles per second or Hertz.
N	=	Number of turns in a coil of stator winding
F	=	Frequency = Pn/120
Where P	=	Number of poles
N	=	revolutions per second of rotor.

From the expression, it is clear that for the same frequency, number of poles increases with decrease in speed and vice versa. Therefore, low speed hydro turbine drives generators have 14 to 20 poles where as high speed steam turbine driven generators have generally 2 poles. Pole rotors are used in low speed generators, because the cost advantage as well as easier construction.

The excitation currents for typical 500 MW generators range from 3700 to 5100 amps and sliding electric contracts and components need frequent attention and maintenance due to heating caused by brush friction and brush losses. Present trends are towards eliminating the slip-rings and brush gear entirely and use what are now called brushless exciters.

In any development programme, the costs of material and labour involved in manufacturing and erection must be a basic consideration. Coupled very closely with these considerations is the restriction is size and weight imposed by transport limitations.

GENERATOR COMPONENTS

Rotor

It is the rotating part of generator and revolves, in most modern generators, at a speed of 3,000 revolutions per minute. It is also an electromagnet and carries a fairly high current. The passage of the current through the windings generates heat but the temperature must not be allowed to become so high, otherwise difficulties will be experienced with insulation. To keep the temperature down, the cross section of the conductor could be increased but this would introduce other problems. In order to make room for the large conductors, this would cause mechanical weakness. The problem is really to get the maximum amount of copper into the windings without reducing the mechanical strength. With good design and great care in construction this can be achieved. The rotor is a cast steel ingot, and it is further forged and machined. Very often a hole is bored through the centre of the rotor axially from one end of the other for inspection. Slots are then machined for windings and ventilation.

Rotor winding

Silver bearing copper is used for the winding with mica as the insulation between conductors. A mechanically strong insulator such as micanite is used for lining the slots. Later designs of windings for large rotor incorporate combination of hollow conductors with slots or holes arranged to provide for circulation of the cooling gas through the actual conductors. When rotating at high speed. Centrifugal force tries to lift the windings out of the slots and they are contained by wedges. The end rings are secured to a turned recess in the rotor body, by shrinking or screwing and supported at the other end by fittings carried by the rotor body. The two ends of windings are connected to slip rings, usually made of forged steel, and mounted on insulated sleeves.

Rotor balancing

When completed the rotor must be tested for mechanical balance, which means that a check is made to see if it will run upto normal speed without vibration. To do this it would have to be uniform about its central axis and it is most unlikely that this will be so to the degree necessary for perfect balance. Arrangements are therefore made in all designs to fix adjustable balance weights around the circumference at each end.

Stator

Stator frame: The stator is the heaviest load to be transported. The major part of this load is the stator core. This comprises an inner frame and outer frame. The outer frame is a rigid fabricated structure of welded steel plates, within this shell is a fixed cage of circular and axial ribs. The ribs divide the yoke in the compartments through which hydrogen flows into radial ducts in the stator core and circulate through the gas coolers housed in the frame. The inner cage is usually fixed in to the yoke by an arrangement of springs to dampen the double frequency vibrations inherent in 2 pole generators. The end shields of hydrogen cooled generators must be strong enough to carry shaft seals. In large generators the frame is constructed as two separate parts. The fabricated inner cage is inserted in the outer frame after the stator core has been constructed and the winding completed.

Stator core: The stator core is built up from a large number of 'punchings" or sections of thin steel plates. The use of cold rolled grain-oriented steel can contribute to reduction in the weight of stator core for two main reasons :

- There is an increase in core stacking factor with improvement in lamination cold rolling and in cold buildings techniques.

- The advantage can be taken of the high magnetic permeance of grain-oriented steels of work the stator core at comparatively high magnetic saturation without fear or excessive iron loss of two heavy a demand for excitation ampere turns from the generator rotor.

Stator Windings

Each stator conductor must be capable of carrying the rated current without overheating. The insulation must be sufficient to prevent leakage currents flowing between the phases to earth. Windings for the stator are made up from copper strips wound with insulated tape which is impregnated with varnish, dried under vacuum and hot pressed to form a solid insulation bar. These bars are then place in the stator slots and held in with wedges to form the complete winding which is connected together at each end of the core forming the end turns. These end turns are rigidly braced and packed with blocks of insulation material to withstand the heavy forces which might result from a short circuit or other fault conditions. The generator terminals are usually arranged below the stator. On recent generators (210 MW) the windings are made up from copper tubes instead of strips through which water is circulated for cooling purposes. The water is fed to the windings through plastic tubes.

Generator Cooling and Sealing System

Rotor Cooling System

The rotor is cooled by means of gap pick-up cooling, wherein the hydrogen gas in the air gap is sucked through the scoops on the rotor wedges and is directed to flow along the ventilating canals milled on the sides of the rotor coil, to the bottom of the slot where it takes a turn and comes out on the similar canal milled on the other side of the rotor coil to the hot zone of the rotor. Due to the rotation of the rotor, a positive suction as well as discharge is created due to which a certain quantity of gas flows and cools the rotor. This method of cooling gives uniform distribution of temperature. Also, this method has an inherent advantage of eliminating the deformation of copper due to varying temperatures.

Hydrogen Cooling System

Hydrogen is used as a cooling medium in large capacity generator in view of its high heat carrying capacity and low density. But in view of it's forming an explosive mixture with oxygen, proper arrangement for filling, purging and maintaining its purity inside the generator have to be made. Also, in order to prevent escape of hydrogen from the generator casing, shaft sealing system is used to provide oil sealing.

The hydrogen cooling system mainly comprises of a gas control stand, a drier, an liquid level indicator, hydrogen control panel, gas purity measuring and indicating instruments, valves and necessary instruments necessary for controlling and the inter -connecting piping.

The system is capable of performing the following functions:

- Filling in and purging of hydrogen safely without bringing in contact with air.
- Maintaining the gas pressure inside the machine at the desired value at all the times.
- Provide indication to the operator about the condition of the gas inside the machine i.e its pressure, temperature and purity.
- Continuous circulation of gas inside the machine through a drier in order to remove any water vapour that may be present in it.
- Indication of liquid level in the generator and alarm in case of high level.

Stator Cooling System

The stator winding is cooled by distillate which is fed from one end of the machine by teflon tube and flows through the upper bar and returns back through the lower bar of another slot.

Turbogenerators require water cooling arrangement over and above the usual hydrogen cooling arrangement. The stator winding is cooled in this system by circulating demineralised water (DM water) through hollow conductors. The cooling water used for cooling stator winding calls for the use of very high quality of cooling water. For this purpose DM water of proper specific resistance is selected. Generator is to be loaded within a very short period if the specific resistance of the cooling DM water goes beyond certain preset values. The system is designed to maintain a constant rate of cooling water flow to the stator winding at a nominal inlet water temperature of 40 deg.C.

As it is closed loop working, the cooling water is again cooled by water which is also demineralised to avoid contamination with any impure water in case of cooler tube leakage. The secondary DM cooling water is in turn cooled by clarified water taken from clarified water header.

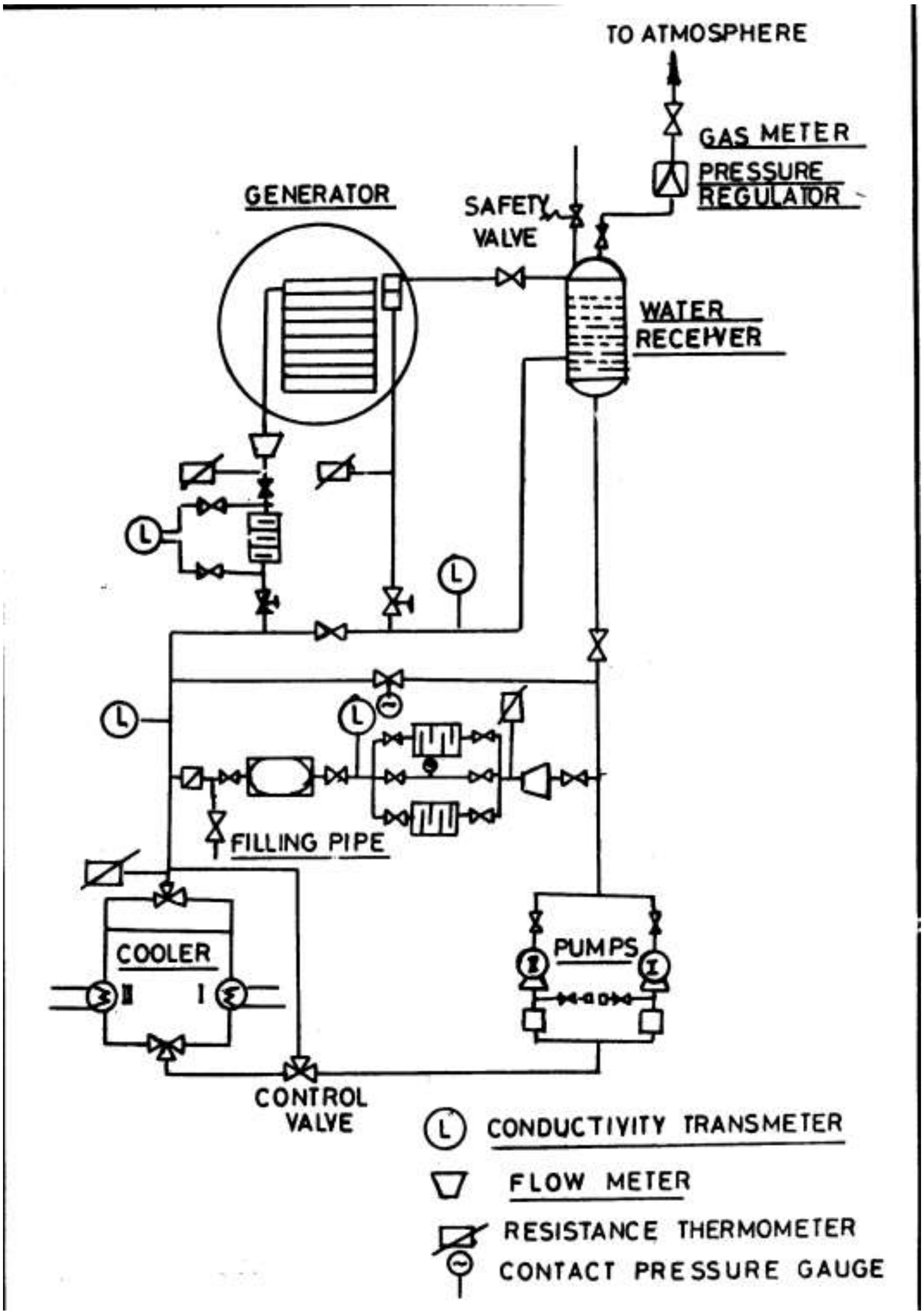
Description and working of the system : The closed loop cooling system consists of the following :

- 2 x 100% duty AC motor driven stator water cooler pumps.
- 2 x 100% duty DM/DM water coolers.
- 2 x 100% duty mechanical filters.
- 2 x 50% duty magnetic filters.
- expansion tank with water jet ejectors.
- 2 x 100% duty AC driven DM water pumps.
- 2 x 100% duty DM/ clarified water coolers.
- DM water make-up tank.
- Associated panel and instrumentation.

Normally one pump, one cooler and one mechanical filter are in operation and the second set acts as stand-by for emergencies. The DM water is supplied through the feed header mounted inside the generator casing towards turbine end. Feed headers are connected to individual upper and lower bar conductors of the stator with the help of teflon houses. Water passes through lower bars along the length to the other end returns through the upper bars of another slot and drain into drain header mounted on the turbine side.

The stator water cooler pumps drive DM water through the coolers, filters and windings. This water is ultimately discharged into a separate compartment known as expansion tank. The drain from stator winding is showered in the hermetically sealed compartment of the expansion tank, which is mounted at a level 5M above generator center line and maintained at a vacuum of 250 to 300mm of mercury to expel the air or any trace of hydrogen coming with the drain water. For maintaining the vacuum in the expansion tank, one water jet ejector has been provided. The water from the expansion tank is again drawn by the pump, cooled in coolers and circulated through stator winding.

The closed circuit DM water is cooled by DM water supplied from Station DM water plant. The use of DM water on secondary side eliminates contamination of the closed circuit DM water which can cause the tripping and shut down of the units.


TO ATMOSPHERE
GAS METER
PRESSURE
REGULATOR
GENERATOR
SAFETY
VALVE
WATER
RECEIVER
FILLING PIPE
COOLER
PUMPS
CONTROL
VALVE
CONDUCTIVITY TRANSMETER
FLOW METER
RESISTANCE THERMOMETER
CONTACT PRESSURE GAUGE

Generator Sealing System

Seals are employed to prevent leakage of hydrogen from the stator at the point of rotor exit. A continuous film between the rotor collar and the Seal Liner (in the case of THRUST TYPE Seals) is maintained by means of the oil at a particular pressure above the casing hydrogen gas pressure. The thrust pad is held against the collar of rotor by means of thrust oil pressure, which is regulated in relation to the hydrogen pressure and provides a positive maintenance of the oil film thickness.

The surface of the Seal liner babbited and the radial canals are milled to provide the Stability of the film under various conditions and also to avoid the whirling of the oil. The flow through the film is Sufficient to maintain the temperature of oil within limits and the temperature is monitored continuously by means two capsule type resistance thermometers. In order to prevent the circulation of the induced current, the Seal Body of the exciter is insulated from the Stator. The shaft sealing system mainly consists of AC oil pump ,DC oil pump ,Oil Injector , Differential pressure regulator , Damper tank.

During normal operation, the oil is drawn from governing oil as well as lubricating oil system to obtain the required quantity of seal oil at required pressure. The pressure and flow of oil at the outlet of the injector can be controlled by regulating the oil supply from the governing oil system into the injector with the help of a differential pressure-regulating valve.

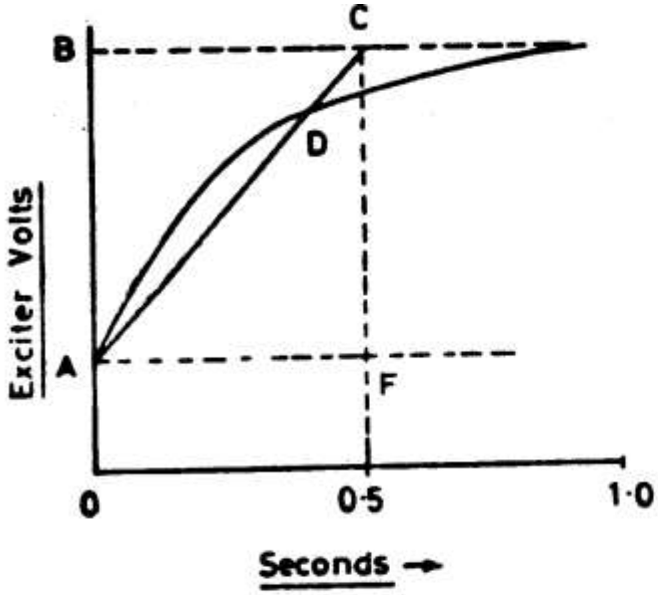
Bearings

Antifriction bearings are used for small alternators but oil lubricated bearings are more in use for larger ones. Self contained ring-oiled bearings are used for horizontal shafts. But for heavy applications and high speeds, ring oiling is supplemented by recirculation of externally cooled oil. An emergency supply of oil is also maintained in such systems as a stand by for failure of main supply. Load based babbits are used for journal bearings. Tin base is used for heavy duty application.

Bearing supports are designed to afford some degree of alignment of bearing bushing but they are sufficiently rigid so as not to affect the critical speeds of shaft system.

Excitation System

Characteristics



Nominal exciter response is defined as the rate of increase of exciter voltage in volts per second. Refer the graph, the, slope of line AC = AB/AF Volts/sec

It is sometimes considered that exciter response in terms of the generator no-load excitation voltage may introduce errors when dealing with response under load conditions. Exact values can be obtained only by testing and results of tests done indicate that exciter response under loaded generator conditions is not markedly different from the value under no-load conditions.

The excitation system of a generator comprises of :

- The main exciter
- The pilot and auxiliary exciters
- The voltage control system

Development of Excitation System

Initially the DC Excitation system was being used. The development of improved techniques resulted in the increased capacity of generators, which in turn raised the demand of excitation power. But it was found that DC excitation could not meet the demands of large capacity turbo-generators due to the following reasons:

High excitation currents at comparative low voltage were required and these would entail a large number of brushes operating on the exciter commutator. This will create difficulties in operation and will require extensive maintenance of commutator and Brush Gear.

The other disadvantage of DC exciter is that commutator may be satisfactory during steady state but during load fluctuations, there is a risk of flash over at the commutator. The maximum pheripherial speed of commutator for proper operation should not be more than 45 meters per second.

Reliability is one of the main requisites of excitation system of the generator. This accelerated development of AC excitation system, where AC generator alongwith rectifier system is used for field excitation. In India, practice is to use DC excitation system for 100/110 MW system and AC excitation for higher capacity turbogenerators.

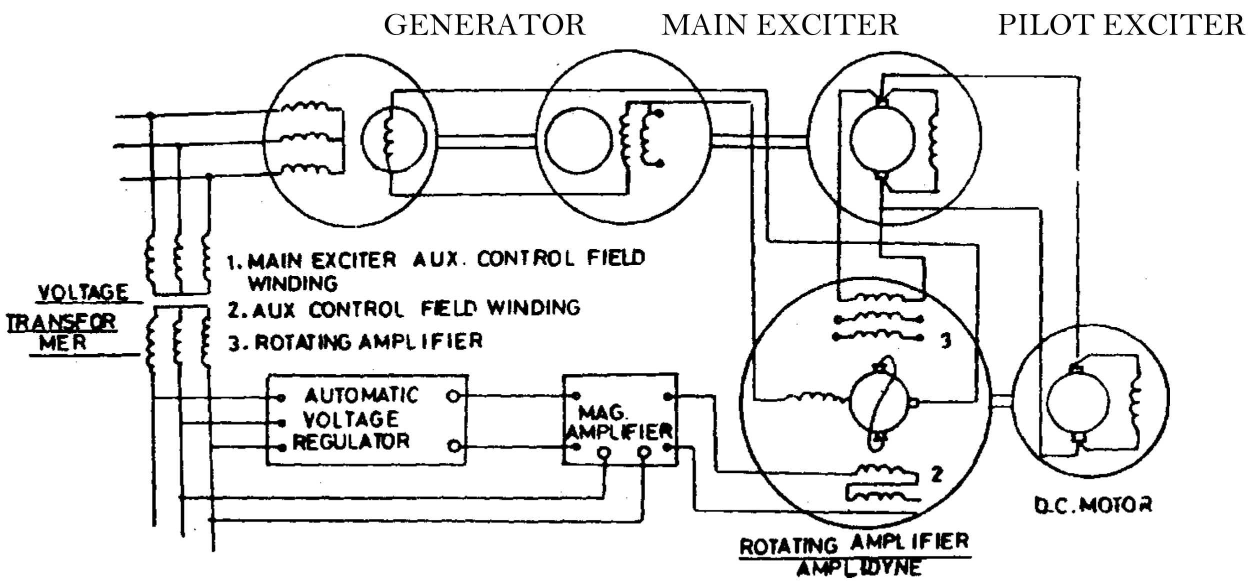
DC Excitation System

Direct current excitors are shut wound machines and compounding can be included to improve response. The open-circuit characteristics and basic diagram of a self excited compounded shut wound exciter are shown. It is important to note the unstable voltage region HB on the open circuit characteristic of the exciter. Since OE is the excitation current when voltage BE is across the shunt field. BE/OE is the value of the critical resistance of the circuit. The line of this critical resistance coincides with slope of the voltage characteristic therefore, the voltage is indefinite and can vary freely between the valve M due to the exciter permanent magnetism, and value B the voltage due to field current OE. Even small temperature increases in the field winding will contribute to voltage in stability. A method of overcoming this effect is to insert a saturation liner behind each pole piece. Because of reduced magnetic section the liner is saturated much sooner than the pole body; thereby introducing the required non-linearity in the open circuit characteristic. One adverse effect of the saturation liner however, is to depress the ceiling voltage of the exciter.

Ceiling Voltage and Current

These are the maximum on load values that can be sustained under field forcing (i.e. field boosting) conditions. Except for small generators the main exciter is usually separately excited from a pilot exciter. The advantages of this system are :

- Quicker response
- Stable operation at low voltages i.e. it will excite stably at high values of field resistance.



Basic Schematic Diagram of D.C. Excitation System

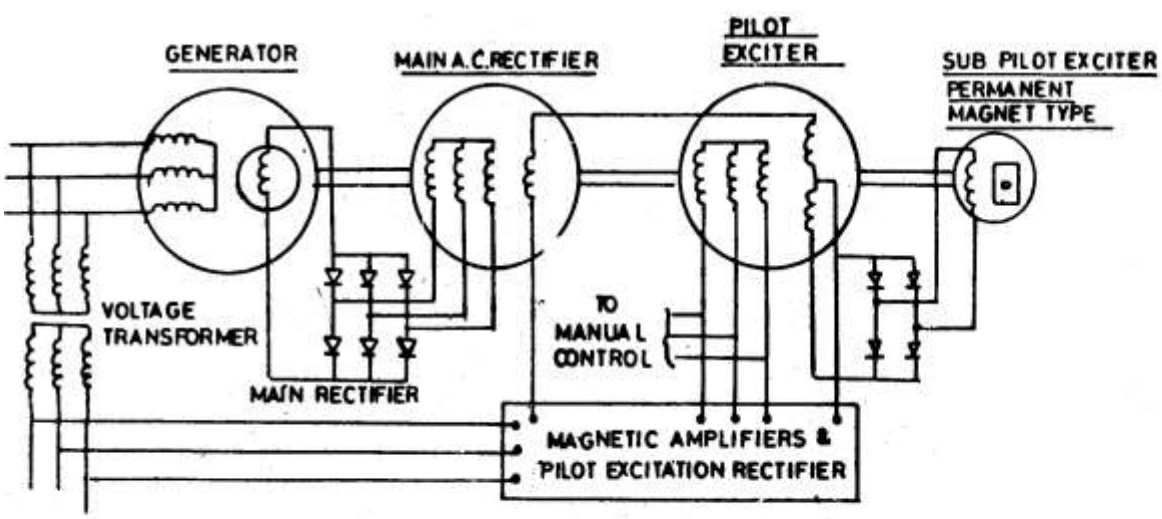
Exciter field windings can comprise two or three separate windings. The main field winding is often duplicated to provide parallel current paths to reduce contact wear and field rheostat wear.

The provision of a negative field gives a negative bias in the exciter by which response is improved when load is thrown off. It also improves the lowering response of the exciter system following as external fault clearance and reduces the range of main exciter field current needed for a given change in exciter voltage. But this negative field constitutes a constant load on the pilot exciter and necessitates a more powerful positive main field than would be the case without negative bias. These disadvantages are justified. However, on the ground of improve exciter performance, it should be noted that negative excitation like this cannot be achieved in present AC exciter/rectifier systems.

Based on the principle detailed above, the basic schematic diagram of DC Excitation system has been given in figure.

AC Excitation System

The AC exciter for large units gained favour because it was possible to use 2 or 4 pole revolving field type machines possessing all the robustness associated with the generator. Commutator and DC brushgear were eliminated giving place to the simple rotor slip-rings and associated brushgear. A pilot excitor is a necessary piart of the ac excitor system. It is common practice to have pilot excitor, itself an a.c. machine. The pilot excitor can also be a permanent magnet generator. The main a.c. excitor is generally a turbo-type generator. It must operate over a wide voltage and current range with ceiling valves considerably greater than the rated full load valve. Further, more the excitor output must respond quickly to excitation changes at its own rotor terminals. The excitation is controlled by the AVR. The excitation for the pilot excitor is obtained from a permanent magnet of excitor where output is rectified. The pilot output, which excites the field of AC main excitor, is controlled by Automatic voltage regulator. The rectified output of the main exciter than energises the rotor of the synchronous generator. In lieu of main exciter the A.C. supply can be taken from the grid, or generator itself rectified and given to the generator field. This is called static excitation.



Basic Schematic Diagram of A.C. Excitation System

In India for 200/210 MW the following two excitations system have been adopted:

1. High frequency Excitation system with an AC exciter, permanent magnet pilot exciter and an un-controlled rectifier.

2. Generator potential fed static Excitation system with controlled rectifiers (SCR) and a rectifier transformer.

In addition the following salient features are incorporated in the design of excitation system:

- Rapid de-excitation
- Contactless field forcing
- Reactive load sharing for parallel operation
- Transformer drop compensation
- Follow-up circuit for smooth change over from auto to manual
- Error detection-proportional type
- Stabilizing feed back
- Rotor current limiter and over excitation limiter with time delay, in static and
- AC machine excitation respectively.
- Slip stabilizer for static excitation system only.

High Frequency Excitation

The high frequency excitation system, adopted in 200/210 MW TG is based on the principle of separate excitation with the help of a 500 C/S A/C main and 400 C/S pilot exciter in conjunction with the static rectifying unit. Both the exciters are directly mounted on the TG shaft. The main exciter HFEX is an inductor type generator which has three phase AC windings and four field windings on the stator and no winding on the rotor which enhances its reliability and maintenance. The pilot exciter (PEX) is a permanent magnet type and serves as a source of stable supply to the power magnetic amplifiers of AVR and the manual excitation of flux at various operational conditions. The rectifying unit is water -cooled, three phase static converter, which rectifies the HFEX output and fee the turbo-generator fields.

High Frequency Induction Alternator The DC excitation winding is housed in the stator and is coaxial with the stator core. The construction is symmetrical about the DC windings. The rotor and stator are slotted. There are two stator slots for each rotor slot. The flux path is as shown i.e all the rotor teeth on one side are poles and all the other teeth on the opposite side S-poles. The output is obtained by variation of the stator teeth flux caused by variation of the reluctance of the air gap caused by the movement of the rotor teeth.

Automatic Voltage Regulation

AVR Components

Compounding Device: The compounding device produces excitation in addition to the one produced by the generator exciter, depending upon the load current. This device consis ts of three phase auxiliary compounding transformer (Aux T corn) and a group of selenium rectifiers (PCI) connected in three phase bridge scheme. The compounding device is directly connected through g.c.s switch to the main field winding of the generator exciter. The compounding current setting is adjusted by means of three phase rheostat (RhI). On a.c. side the compounding device is connected to the current transformers rated for 5A secondary current. Output current of compounding device appear after a certain value of current which is called threshold current in the generator stator. This threshold current for compounding depends upon-excitor voltage and also upon RhI setting. At BTPS compounding does not affect the generator excitation till a minimum of stator current (=1200A) has reached. After compounding coming into operation output current of this device practically remains proportional to the generator stator current. When stator current increases, output of it increases, this additional feed to the excitation winding of exciter will raise exciter voltage and this in turn leads to the rise of generator rotor current and in this way compounding device accomplished the generator excitation regulation.

Electro Magnetic Voltage Corrector: Electromagnetic voltage corrector produces on an additional field current depending upon the generator voltage. This additional field current is supplied to the additional field winding of the main excitor.

The electro-magnetic voltage corrector incorporates a measuring element and a magnetic amplifier with function as power element. A three-phase saturable transformer serves as a measuring element, the primary current of which shows strong non linear dependence upon generator voltage while secondary voltage shows a linear dependence upon generator voltage. The current in the control winding of the magnetic amplifier is determined by the difference between the voltage drop across the adjustable rheostat (Rh3) and the voltage across the secondary winding of the measuring transformer. The above voltage drop results from the current variations in the primary winding of the transformer. Hence a decrease in the generator voltage will result in a non-linear decrease of the primary current of the measuring transformer. Therefore, a reduction of the voltage drop across the adjustable rheostat will be much stronger than the change of the secondary voltage of the measuring transformer. Due to this fact the control current of the magnetic amplifier will show a rise thereby increasing it output current.

On the other hand when the generator voltage raises, the voltage across the rectifier RC 4 fed from the secondary winding of measuring transformer will become less than that across the adjustable rheostat, therefore RC4 become unconductive. The reverse polarity current will flow through the control winding of magnetic amplifier, thus reducing the output current of the magnetic amplifier and in turn the excitation current of exciter. The generator voltage is brought to the normal condition. A corrector transformer is connected to the output of the magnetic amplifier. It serves to match the corrector output with the excitation winding by changing the transformation ratio.

In order to reduce the corrector output current within the range of higher voltage, which may cause unstable operation of AVR, the corrector transformer has a compensating winding connected in opposition to the primary one and in series with non linear choke.

Stability

In high-sensitivity automatic voltage regulating system it is necessary to incorporate some means of insuring stability otherwise 'hunting' of voltage & 'over shoot' occur.

The method employed depends on transient feed back of the exciter armature voltage into magnetic amplifier. The exciter armature is connected to control winding stabilizing transformer.

The primary winding of the stabilizing transformer is connected to the exciter output voltage though additional resistance (ARSI) to limit the current. The secondary winding is connected to a special magnetic amplifier control winding which serves as a stabilizing one.

Regulation of Excitation

The turbo generator field regulation is achieved by varying the main exciter (HFEX) voltage. Excitation of the HFEX is varied by means of a transistorized automatic voltage regulator (AVR) having power magnetic amplifiers at its output stage or with the help of a field rheostat (IFRH) under manual regulation (MR). The AVR is quick acting and has zero dead bands. The AVR provides the excitation requirements of HFEX for both steady state as well as transient operational conditions of the turbo generator.

The AVR provides the maximum limit of field forcing to two times the rated field voltage and current of the turbo-generator when the drop in terminal voltage as 5% or more of the present terminal voltage value. Regulation of reactive current is provided in the range of 0 to 4% of the turbo-generators rated voltage value.

The manual excitation regulation is carried by the field rheostat IFRh with remote control of the smooth automatic changeover of excitation control from AVR to manual, in case of AVR failure, is achieved with the help of matching circuit, Field forcing is not provided with manual regulation.

Magnetic amplifiers at its output stage or with the help of a field rheostat (HFRh) under manual regulation (MR).

The automatic voltage Regulator (AVR) is quick acting and has zero dead band. The AVR provides the excitation requirements of HFEX for both steady state as well as transient operational conditions of the turbo generator. The AVR provides the maximum of field forcing to two times the rated field voltage and current of the turbo generator is 5% or more of the present terminal voltage value.

Regulation of reactive current drop is provided in the range of 0 to 4% of the turbo generators rated voltage value. The annual excitation regulation is carried out by the field rheostat IFRh with remote control. The smooth automatic changeover of excitation control from AVR to manual is carried out in case of AVR failure.

5. Miscellaneous Facilities

Coal Transportation & Handling

Coal Transportation System

Each of the project requires transportation of large quantity of coals from the coal mines to the power station site of the order of 30,000 tones per day for a typical 2,000 MW station. This enormous coal requirement is being met from open cast mines. Each super Thermal Power Project has been linked to a particular coal mine to meet its coal requirements for the span of its entire operational life. Techno-economic study conducted for coal transportation from mines to power station has revealed that captive merry-go-round (MGR) rail transportation system is most economic and is also reliable. This system calls for high-speed load-outstation at the mines, which have the following advantages:

The high speed load outstation consists of one or two loading silos depending upon the coal requirement of the linked power station. The holding capacity of the loading silo is such that is adequate to fall at least one complete rake of wagon and in some cases two rake. The capacity of the silos for the project usually varies between 2400 ton/4000 ton. The silos are cylindrical and are of RCC construction being fed by twin belt conveyors. The capacity of the conveyors is based on peak daily coal requirement of the power station linked to mine. 100% standby conveyor capacity is provided for complete reliability of feeding arrangement to the silo. For accurate weighing of coal, two in-motion weight bridges (one before the loading silo and another after the silo) are provided for registering the tare and gross weight of the wagons. Hydraulically operated horizontal snap gates are provided at the mouth of silos to control the feed of coal to wagons. The run of mine coal is sized to 200 mm by the primary crushing arrangement at the mine end. A sampling unit suitable for 20 mm size coal is provided at the feed point of the loading silo to collect samples for quality analysis.
Since there is generally only one source of coal to the power plant, and independent closed circuit is provided for transporting coal. It is entirely independent of the conventional of the railway system. Dedicated unit trains are deployed to transport coal from mines to power stations. The loading operation of

the coal rake takes place while it is moving under the silo at a present speed of 0.8 k.m. per hr. The loading time for each wagon is one minute. Wagons are provided with bottom discharge hoppers fitted with pneumatically operated automatic door actuating mechanism. For unloading of coal from wagons and underground track hopper is provided at the power station end. Line side equipment is installed by the track hopper for initiating the opening of doors in groups of 10-14 wagons. The unloading operation of 60 tone per load wagon takes about 20/30 seconds.

The track hopper is designed to have an effective minimum holding capacity of the train load and is normally of 200-250 m length. The complete operation of loading, unloading and running of trains is dovetailed is such a manner that there is no holdup in the operation of the MGR system. The capacity of reclaim conveyors installed below track hopper is such that the track hopper is evacuated before the arrival of the next train.

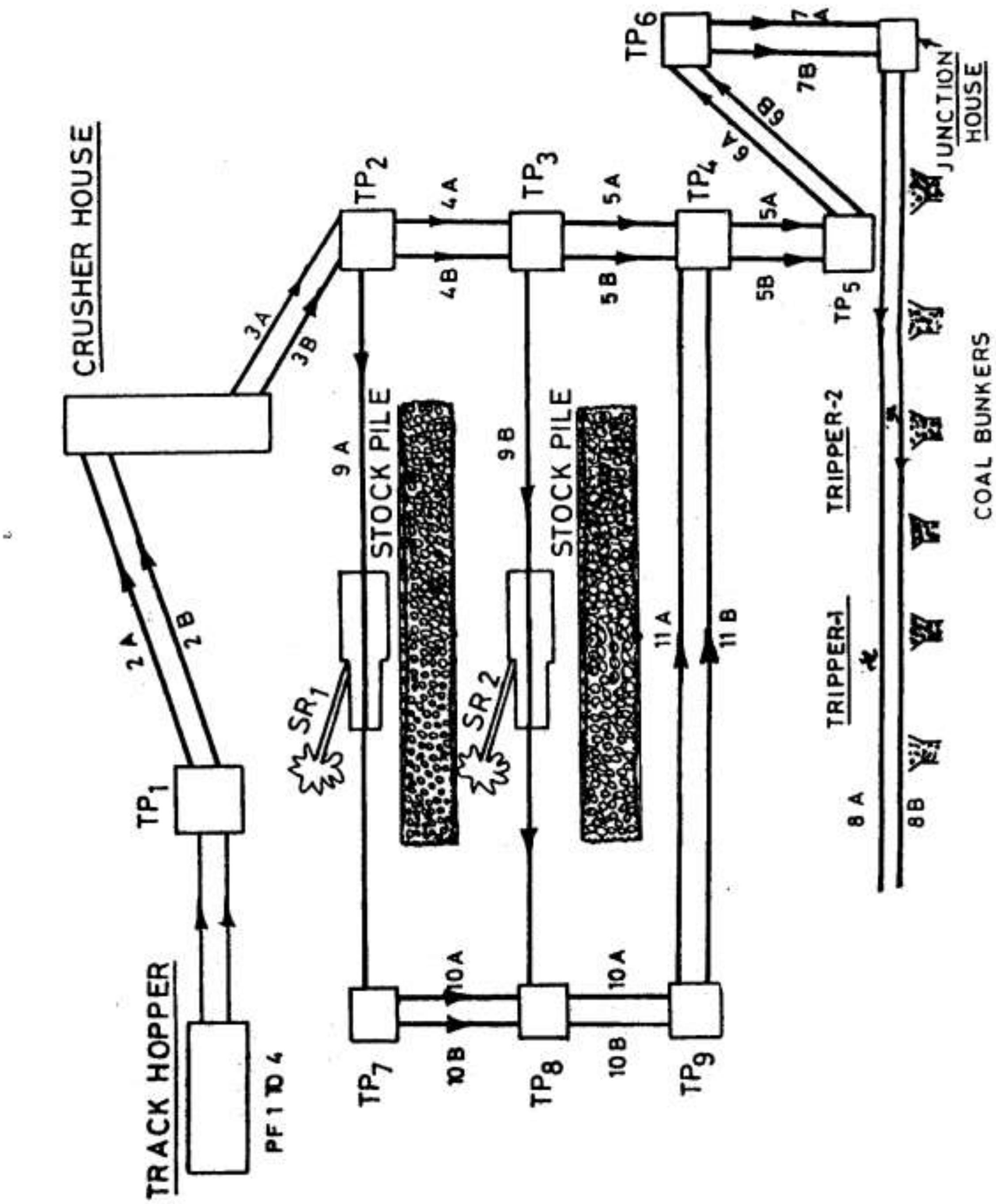
Coal Handling System

In the coal handling system, three coal paths are normally available

- Path A - direct conveying of coal from track hopper to boiler bunkers
- Path B - from track hopper to stockyard
- Path C - from stockyard to boiler bunkers.

The storage facilities at the stockyards have been provided only for crushed coal.

The coal handling system is designed to provide 100% standby for all the equipment and conveyors. The conveyor capacities are determined by the fact that a single steam of conveyors shall meet the daily MCR coal requirement of all the units in 12-14 operation hours per day. The coal handling system is designed such that both the steams can be operated simultaneously, if required.
The capacity of the coal handling system for the present super thermal stations varies from 1200 to 2000 t/h, normally, for a stage of 1000 MW, the conveyor capacities are rated 1200-1700 t/h depending upon the gross calorific value of the coal. The gross calorific value of typical power grade Indian coal is normally in the range 2700-4300 kcal/kg. A typical schematic representation of a coal handling system has been shown below.



The 200mm coal as received at the track hopper is fed to the crusher house through a series of conveyors. In the crusher house, four crushers of 50% capacity are provided and these are preferred to two crushers of 100% capacity because of increased reliability and possible higher availability.

A series of parallel conveyors thereafter are designed either to carry crushed coal directly to the roller bunkers or to divert it to the stockyard. To feed coal into bunkers, mobile trippers have been provided over bunker conveyors.

The coal mills and, therefore also, the bunker conveyors of the 200 MW units of the earlier projects are provided between boiler and turbo-generator building. However, for better mill maintenance, accessibility, and to reduce coal dust nuisance in the turbine plant area, coal mills and bunker conveyors are now being place between boiler and electrostatic precipitator. The mills for 500 MW units are located on both sides of the boiler.

Coal handling System - Equipments

The various equipments involved in the coal handling system have been described in this section and they are i) idlers, ii) pulleys, iii) Conveyor belt, iv) drive Unit, v) take- ups, vi) Skirt board, vii) scrapper, viii) crushers, ix) vibrating screen, x) Stacker-cum - reclaimer, xi) magnetic separators, xii) plough feeder, xiii) ring-granulator, xiv) Eliptex feeder, xv) motorised tripper.

Idlers Idlers consist essentially of rolls made out of seamless steel tube enclosed fully at each end. The idlers support the conveyer belt and enable it to travel freely without much frictional losses and also keep the belt trained properly. The proper training is achieved on the principle that the belt will move towards the roll which touches the belt first in the direction of travel. Thus slight adjustment of the one side of idler base in the direction of belt travel will move the belt towards the opposite side since the pulley roll on opposite side will come in contact with the belt first due to swivelling of the idler caused by adjustment of the base.

Impact idlers These are provided with rubber discs for cushioning effect at the loading points and protect the belt from damage which may be caused otherwise due to heavy impact of material falling on belt.

Return Idlers Rubber disc return idlers are suitable when materials are damp or sticky or tend to build up on conventional tube type return idler thus causing the off centre travel of the belt. These are also preferred where abrasive materials rapidly deteriorate metal rolls or when moisture tends to freeze on the belt surface.

Pulleys Pulleys are made of mild steel. Rubber lagging is provided to increase the friction factor in between the belt and the pulley.

Conveyor Belt The conveyor belt consists of layers or plies of fabric duck, impregnated with rubber and protected by a rubber cover on both sides and edges. The fabric duck supplies the strength to withstand the tension created in carrying the load while the cover protects the fabric carcass. Heat resistant belting is always recommended for handling materials at a temperature over 66 deg C.

Drive Unit This comprises of motor coupled to reduction gear box with the help of flexible couplings on the high speed shaft of the gear box. For inclined conveyors, bold backs are incorporated in the gear boxes to prevent running back of the conveyor under loaded condition. With the provision of the fluid coupling on the input side, the motor starts under no load conditions and the conveyor moves only when the motor reaches its full speed. This also eliminates the starting shock on the conveyor components.

Take Ups All the conveyors are provided with take up which facilitate the effective functioning in the following ways:

To maintain a slack side tension necessary for the drive to operate the belt.

To keep sag of belt between idlers at a point where require horsepower will be at a minimum and load will move with least disturbance over idlers.

Skirt Board Skirt boards are used in conjunction with chutes at the trail end. They guide the materials centrally on the belt while loading until it has settled down on the belt. It consists of a Fabricated Frame mounted along the conveyor length with the necessary supports. The skirt rubber is attached at the bottom keeping uniform pressure on the belting.

Scrapper Conveyors are provided with scrapers at the discharge pulley in order to clean the carrying side of the belt and avoid the wear of return idlers due to the built up material on idler rolls. It is important that care should be taken to ensure that the scraper is held against the belt with the pressure sufficient to remove material without causing damage to the belt due to excessive force exerted by wiper. In case of counter weighted & spring loaded scrapers the pressure is altered by adjusting the weights on the arm or by adjusting the springs respectively. Wherever there is any danger of spilled material getting wedged between the tail pulley and the belt, a V plough scraper is mounted a little ahead of tail pulley on the return run of the belt.

Crusher The role of crusher is to crush the coal from 200 mm to 20 mm size of coal received from the vibrating screen. This is accomplished by means of granulators. These granulators are of ring type and there are about 37 crushing elevations. In each elevation, there are four granulators; two of plain type and two of tooth type. These have been arranged in such a way that the two of the same type are not side-by-side. The granulators are of manganese steel because of their work hardening property.

The coal enters the top of the crusher and is crushed between rotating granulators and fluid cage path. This crushed coal through a chute falls on belt feeder. Normally these crushers have a capacity of around 600 tons per hour.

Vibrating Screen The function of the vibrating screen is: -

To send the coal having size of less than 20mm to belt feeder through the bypass chute bypassing the crusher and to send the coal of more than 20mm size to the crusher. The screen is operated by four V-belt connected to motor. The purpose of the vibrating screen is such that when the unbalanced shaft is rotated with motor the coal particles travel along the screen. The vibration on the screen are damped by four springs mounted below the screen. The coal on the screen, while in running condition, comes into the crusher. Generally in each crusher there are four vibrating screens having a capacity of around 600 tons per hour.

Stacker-cum-reclaimer This is used for stacking and reclaiming the coal from stock yard. Generally two stacker claimers have been provided at thermal projects. Their normal capacity is 200 tons per hour and maximum design capacity is 450 tons per hour.

The stacker reclaimer generally consists of (a) bucket wheel or digging wheel (b) boom conveyor. While the belt conveyor carrying the coal for the stock yard is in the same direction but the direction of the boom conveyor with respect to stacking and reclaiming is opposite.

Magnetic Separators

This is an electromagnet placed above the conveyor to attract magnetic materials. Over this magnet there is one conveyor to transfer these material to chute provided for dumping at ground level. Because of this, continuous removal is possible and also it is not necessary to stop the electric supply to the magnetic separators for removal of separated materials.

Vibrating Feeder

It is used for throwing the coal on the underground conveyor belt from where coal goes to the bunker. Coal from the stockyard, with the help of bulldozer, is taken to the vibrating feeder via reclaimed hopper and underground conveyor belt. In case the bunker requirement is more that the capacity of crusher or stacker reclaimer, then with the help of bulldozer the coal is sent to the bunker from the stock yard, through these feeders.

Trippers The tripper is provided in the conveyor to stack the material at desired location on either side or along the conveyor with the help of chute/chutes fitted with the tripper itself. The tripper is provided with wheels, which moves on rails, parallel to conveyor. These trippers have a rigid welded steel frame to resist shock and minimise distortion. There are mainly three types of trippers. They are a) Motorised tripper b) Belt propelled-manually operated tripper c) winch driven tripper.

Motorised Tripper Motorised tripper, propelled by independent motor, is used wherecontinuous and uniform distribution .of material along the conveyor is required or where the tripper is to be moved or reversed frequently. It can be automatically reversed at end of its travel with the help of limit switches carried on the tripper.

Belt propelled-manually operated tripper The belt propelled tripper is used where travel distance and direction will be manually conrolled. Power to move the tripper is obtained from conveyor belt and is transmitted from the pulley shaft to the tripper wheel through the spur gear, bevel gear, floating shaft and the reduction gear box.

Winch Driven tripper This tripper is driven by a motorised winch drum located either at the head or at the tail to suit the requirement. In this arrangement elaborate power feeding arrangement is not required, as the drive is located at a fixed place. The tripper can have a push button control for operation either at the drive location or at a remote place as required.

Fuel Oil System

Light oil Transfer & Pumping System

Light oil is used as the fuel for the igniters. Light oil is also required for warming up oil guns to start up the boiler from cold condition when steam is not available for heating heavy fuel oil. Due to low viscosity at ambient temperature it does not require heating and atomization is done by air.

Road tankers discharge oil into a common receiving header through flexible hosepipes. There is provision to unload number of tankers at a time. Oil from the receiver is pumped into the light oil storage tank by light oil transfer pumps of rated capacity. The transfer pump is provided with two simple type coarse filters at the suction.

From storage tank, oil is pumped to burners by light oil pressure pumps at rated pressure. Pressure of oil at the pump discharge is kept constant by automatic pressure regulating valve. Fine filter has been provided at the suction of each pump.

The light oil pumping unit located in the pump house near the day tank draws light oil from day tank and delivers through common piping to the boilers. The light oil pumps are of screw, positive displacement type coupled to electric motors through flexible couplings and mounted on a common frame. At the pump suction there are basket type strainers with suitable vents and drains.

Ash Handling Plant

The ash produced in the boiler is transported to ash dump area by means of sluicing type hydraulic ash handling system, which consists of Bottom Ash System, ash Water System and Ash Slurry System.

Bottom Ash System

In the Bottom ash system the ash slag discharged from the furnace bottom is collected in two water impounded scraper troughs installed below bottom ash hoppers. The ash is continuously, transported by means of the scraper chain conveyor, on to the respective clinker grinders which reduce the lump sizes to the required fineness. The crushed ash from the clinker grinders falls into the ash sluice trench provided below the bottom ash hopper from where the ash slurry is further transported to ash slurry sump aided by the ash sluice channel. If the clinker grinder is not in operation, bottom ash can be discharged directly into the sluice channel through the bifurcating chute bypass the grinder. The position of the flap gate in the bifurcating chute is to be manually changed.

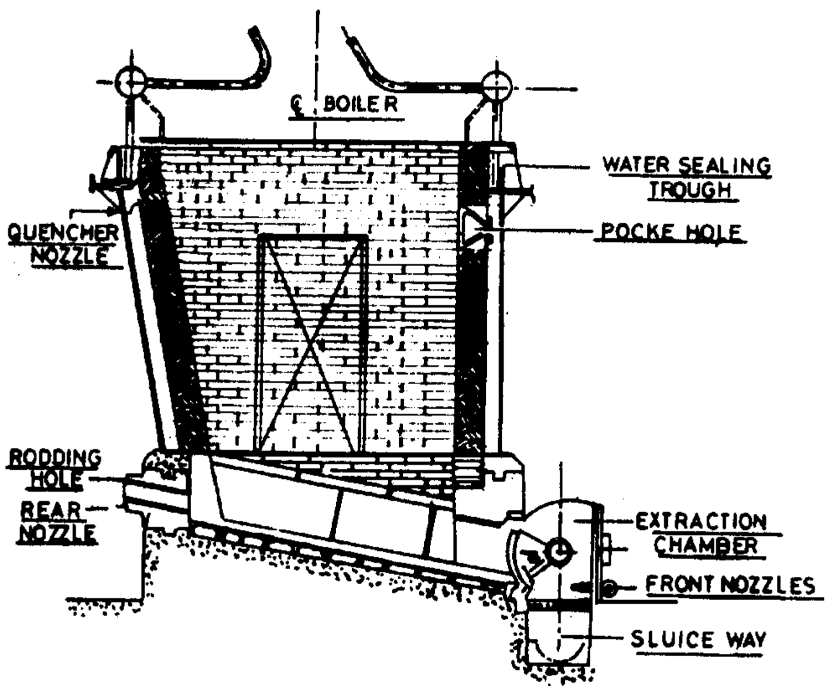
The main types of hoppers used in power stations are described below:

Water Filter Hoppers This consists of a tank made of steel plate. The bottom ash from the boiler falls into water filled tank and is immediately quenched large pieces of ash break up due to thermal shock, thus the ash collected will be of fairly small size and during the disposal not much difficulty in terms of crushing aspects will be encountered. These hoppers may or may not be lined with refractory. The lined hoppers present difficulties with regard to the maintenance of refractory which goes off too frequently due to temperature variations. The unlined hoppers have problems on corrosion for which special coating are recommended.

Quencher Cooled Ash Hopper This uses a series of quenchers located near the top of the hoppers which provide fine spray of water. This ensure that the ash is cooled sufficiently to prevent after combustion and smattering within the hopper. The spray water also keeps the refractory lining of the hopper cool. The quencher type hoppers are not very effective so far as the breaking up of ash due to thermal shocks is concerned. If there is a tendency of slag accumulation of large pieces clinker grinders are normally used.

Fly Ash System

The flushing apparatus are provide under E.P.hoppers (40 nos), economisr hopper (4 Nos), airpreheater hoppers (4 Nos) and stack hoppers (2 nos). The fly ash collected in these hoppers drop continously to flushing apparatus where fly ash gets mixed with flushing water and the resulting slurry drops into the ash sluice channel. Low pressure water is applied through the nozzle directing tangentially to the section of pipe to create turbulance and proper mixing of ash with water. For the maintenance of flushing apparatus plate valve is provided between apparatus and connecting chute.



Quencher Cooled Ash Hopper

Ash Water System

High pressure water required for B.A. hopper quenching nozzles, B.A. hoppers window spraying, clinker grinder sealing scraper bars, cleaning nozzles, B.A. hopper seal through flushing, Economizer Hoppers flushing nozzles and sluicing trench jetting nozzles is tapped from the high pressure water ring main provided in the plant area.

Low-pressure water required for bottom ash hopper seal through makeup, scraper conveyor makeup, flushing apparatus jetting nozzles for all F.A. hoppers excepting economiser hoppers, is tapped from Low pressure water ring mains provided in the plant area.

Ash Slurry System

Bottom ash and fly ash slurry of the system is sluiced upto ash slurry pump along the channel with the aid of high-pressure water jets located at suitable intervals along the channel.

Slurry pump suction line consisting of reducing elbow with drain valve, reducer and butterfly valve and portion of slurry pump delivery line consisting of butterfly valve, pipe and fittings has also been provided.

Circulating Water System

Water Requirements of a Power Station

Bulk requirement of water is used in thermal plants for the purpose of cooling the team in condensers. The requirement of water for this purpose is of the order of 1.5-to 2.0 cusecs/MW of installation. The purpose of condensation is best served by running cold water if it is used one through without the necessity of recalculating the same water for cooling again and again.

Second item of major consumptive use of water is the sluicing out ash that is produced by burning the coal. Of the total quantum of coal consumed in the boiler the percentage of ash may be of the order of 30 to 45%.

Depending on the type of plant, a substantial quantum of water is required in the coal handling plant for the purpose of dust suppression. Since spraying is involved, it is necessary to ensure that the water is reasonably free from silt and other fibrous suspended material.

Lastly, water is also required for various purposes like bearing/equipment cooling and various make-ups in the power station.

Sources of Water Supply

Main sources of water supply are river, reservoirs, natural lakes, canals, wells for small stations, and the ocean for coastal plants.

After working out the total requirement of water for cooling and other purposes. hydrological studies are carried Out for the source to find the reliable discharge available. Dry and wet bulb temperature (Humidity), water temperature, hydrographs of rivers of various years are prepared and the maximum and minimum water level is found out to make techno-economic studies for adopting the type of circulating water system.

Direct Circulation Cooling System

From a River In this system, after studying the hydrological data of the river, if the river water is sufficient to meet the demands of the circulating water system, this method is adopted for cooling. The minimum flow in the main river should not be less than the ultimate requirement of water under all circumstances.

Intake Structure Intake structure is located at such a point where the main channel of the river huge the intake structure bank. Intake structure should not endanger the foundations. The floor level of intake structure should be higher than maximum flood level of the river. Silting at the entrance should be avoided. Techno-economic studies are carried out to fix the capacity of the pump. Suitable trash racks are needed at the entrance of leaves, trees, logs, animals etc. Water drawn through such intake structures can be carried in an open channel or RCC ducts/pipes upto the powerhouse depending on techno-economic studies and site condition with respect to location of the condenser.

Sometimes two stages pumping may become necessary in case of excessive length and head in the condenser system. From the condenser, not water is taken through a pipe to the RCC ducts and then to the open channel. The location of the discharge point should be so fixed that hot water does not cut short to find its way into the intake structure again. Inflow of hot water should not increase the temperature of raw water appreciably and endanger marine life.

From the Ocean Direct circulation can be done from the sea where is no other economical source for a water circulation system. Maximum and minimum tide level is found out and geological studies are also carried out to assess problems to drift deposit. Intake and discharge structures are constructed on separate bays or at adequate "distance apart to avoid short circuit. These structures are constructed generally of precast concrete pipes etc. laid from barges and are loaded with stone. The problem connected with open ocean intake area (i) land movement or unstable bottom, (ii) marine growth control, (iii) problems connected with destruction of fish or clogging of streams by fish and marine life. Thermal shock treatment or addition of chlorine is adopted for checking marine growth. The fish problem can be reduced by the construction of velocity caps which change the direction of flow from vertical to horizontal.

From reservoirs or Pick-up Weirs The design of intakes from a reservoir or pick-up weirs and for direct circulation is in principle, similar to any intake structure for irrigation or hydel channel intake. Apart from desalting when the silt content is high, clarification is also required to be done at least in some cases. Depending on location, advantage can be taken of the symphonic head available for drawl of water. It has to be noted that there may not be much advantage in the capital cost on installation of a pump, but there is definite saving of electric energy by utiliz - ation of a symphonic head.

Closed Circulating System

Closed circulating water system can be sub-divided into two types

- Where the water supply in scarce (by cooling tower spray pond) and
- Where the water supply is ample and hot water can be cooled by surface evaporation from a lake.

In this system of cooling, the same water will be circulated again and again: water which gets hot is cooled by a cooling tower or by lake spread cooling system before being re-used. The quantity of soluble salts in circulating water will increase in case of cooling towers. Generally, arrangements are made to provide for taking the blow down discharge. Substantial quantum of water is lost by evaporation and drift in the process of cooling. This is required to be made up by fresh supply.

Intake Structure The principle of design and construction of intake structure for make-up water is the same as that for once-through direct circulation intake, excepting for the fact that the volume handled in this case is smaller. This makeup water is led to the cooling tower basin. Water is drawn from the cooling tower basin by RCC duct. Proper arrangement of stop log and trash rack is made at the entrance of the water intake channel RCC ducts. Intake ducts are taken along the length of the main powerhouse and entry to the units is made in between the column. The capacity for RCC duct is fixed on 1.1 to 1.5 cusecs/MW. The velocity of water should not be less than 3 ft/sec, and not more than 8 ft/sec. Generally, 5 ft/sec, to 6 ft./sec. velocity is adopted for design of RCC duct. Suitable gates or stop logs should be provided in intake channels to isolate them from the units not under operation and for necessary maintenance and repairs.

Lake Cooling This system can suitably be adopted when a natural lake is available or an artificial lake can conveniently be constructed by construction of a dam and when surface area of such lake even under draw down condition is adequate for the required quantum of cooling. Water is pumped or drawn from one end of the source to condensers and hot water is discharged at the other end into the source at a suitable location so that hot water is not drawn again. Hot water gets cooled in the reservoir by coming in contact with cooler water and air and evaporation. Extent of cooling of hot water depends on :

- Surface area of water
- Ambient temperature
- Reservoir water temperature
- Wind velocity
- Dry and wet bulb temperature i.e. humidity
- Inflow and outflow discharge from reservoir/lake.

Location of intake structure and arrangement : Intake structure is located on the fringe of the reservoir so that the distance from main power house to intake structure is minimum. Elevation of condenser and elevation of minimum water level has a great bearing on the circulating water system. Power houses can be so located that the grade level of power house is about 8 to 10 ft. above high flood level of lake or reservoir. Water is drawn by open earthen channel or by RCC ducts and pumped to the condenser from where it should be able to discharge into the lake at maximum water level by gravity.

But when the layout is so adjusted that the condenser is located below grade level, the cost of intake pumping can be reduced; but the power house has to be protected against seepage of water and flood level of reservoir.

Cooling Towers

Cooling towers are important components of thermal plants where a limited supply of make-up water only is available. Cooling towers thus provide flexibility for selection of sites for thermal power stations even though capital investment and running costs are generally on the high side.

Broadly speaking cooling towers are of two types: i) Mechanical draft cooling towers and ii) natural draft cooling towers. Mechanical draft cooling towers are of two types viz. a) forced draft-cooling towers and (b) induced draft-cooling towers.

Forced draft-cooling tower In this case, motor driven fans located at the base, i.e. ground level, below air into the tower from the sides. The top of the tower is open to the air vapour discharge.

Induced Draft Cooling Towers These days, it is preferred to use induced draft cooling towers where the fan is located at the top and air enters from the openings located at ground level. Air, mixed with vapours, is discharged through a fan stack located at the top of the tower.

Hyperbolic Natural Draft Cooling Towers These are hyperbolic RCC structures supported on RCC columns. Most of structure is empty shell but the lower portion contains a cooling stack over which hot water is distributed by RCC channel or pipe system. The lower portion of shell is open to allow the air to go to the cooling stack supported on the RCC columns, whic h are designed for horizontal load due to wind. A pond is constructed below the tower to catch the cooled water and make-up water for circulation. As the warm water falls in the stack, it gives its heat to the air there, which becomes lighter than the ambient air and a draft is created due to chimney action.

Spacing of cooling Towers

Natural draft cooling towers are so located that air may pass freely into the base of these cooling towers. Generally, these are spaced at three dia. centre to centre at ground level. But clear distance should not be less than 30 to 40 m in any case.
Cooling towers should be away from main and auxiliary buildings, so that they stop circulating air or spray water on buildings. They should not near the switch-yard as this will affect the working life of the structure. In case cooling towers are located near the main national highway, it is likely that there may be fog near the road due to cooling towers. This is likely to affect the traffic on roads.

Auxiliary Cooling Water System

Usually a part of the water to condenser is tapped off and supplied for the following sub-systems :

- Turbine lub oil and gas cooler directly from CW pump discharge
- Bearing cooling system
- D M plant
- General services and miscellaneous cooling

Water Treatment Plant

The objective of water treatment is to produce a boiler feed water so that there shall be (a) no scale formation' causing resistance to passage of heat and burning of tube (b) no corrosion and (c) no priming or foaming problems. This will ensure that the steam generated shall be clean and the boiler plant will provide trouble free uninterrupted service.

As the types of boiler are not alike their working pressure and operating conditions vary and so do the types and methods of water treatment. Water treatment plants used in thermal power plants are designed to process the raw water to a water with vary low in dissolved solids known as "demineralised water". No doubt, this plant has to be engineered very carefully keeping in view the type of raw water to the thermal plant, its treatment costs and overall economics.
Actually, the type of demineralisation process chosen for a power station depends on three main factors :

- The quality of the raw water.
- The degree of deionisation i.e. treated water quality
- Selectivity of resins.

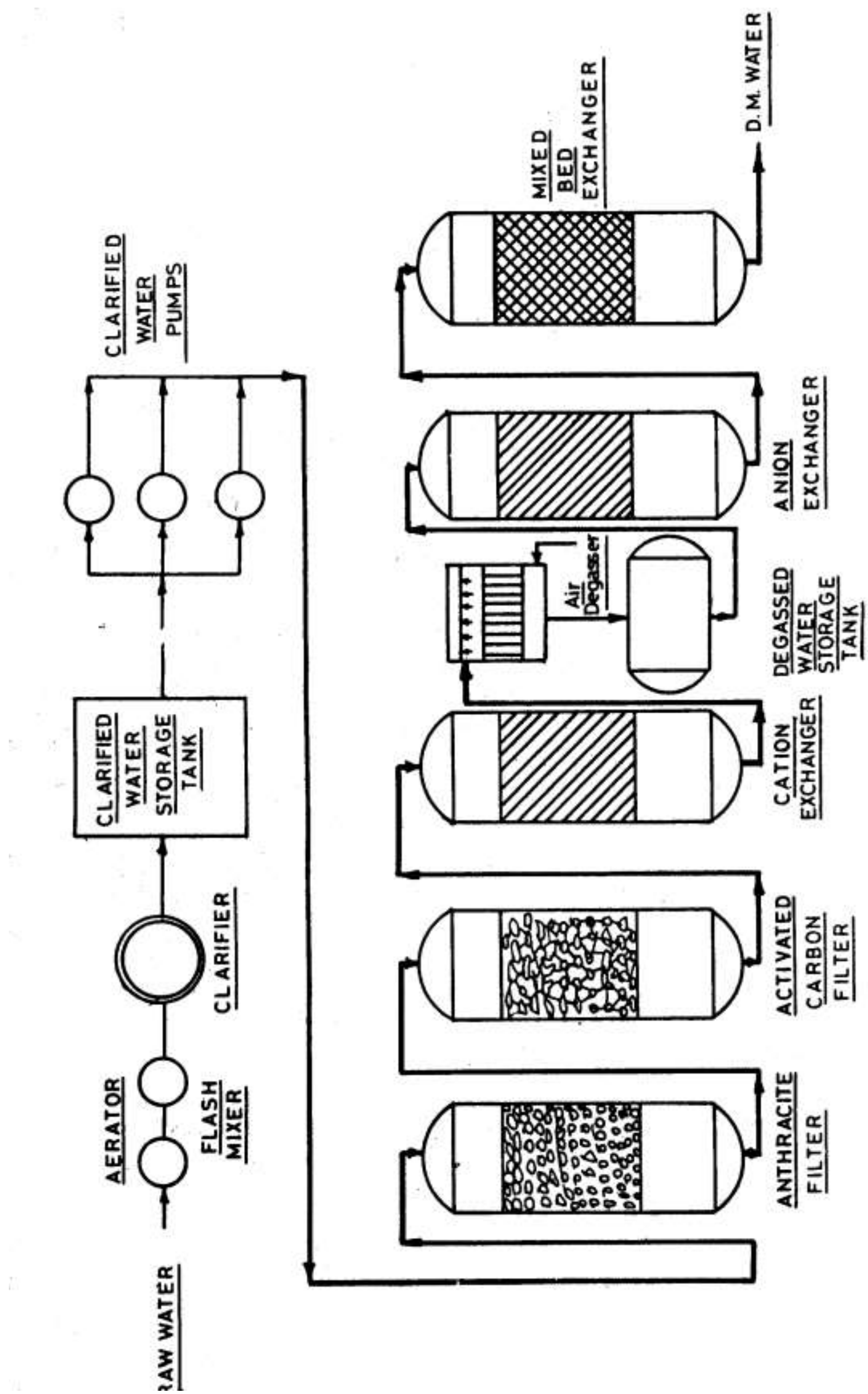
Water treatment process generally made up of two sections : Pretreatment section & De-mineralization section

Pretreatment section

Pretreatment plant removes the suspended solids such as clay, silt, organic and inorganic matter, plants and other microscopic organism. The turbidity may be taken as of two types of suspended solids in water. Firstly the separable solids and secondly the non-separable solids (colloids). The coarse components, such as sand, silt etc, can be removed from the water by simple sedimentation. Finer particles however, will not settle in any reasonable time and must be floculated to produce the large particles which are settle able. Long term ability to remain suspended in water is basically a function of both size and specific gravity. The settling rate of the colloidal and finely divided (approximately 001 to 1 micron) suspended matter is so slow that removing them from water by plain sedimentation is tanks having ordinary dimensions is impossible. Settling velocity of finely divided and colloidal particles under gravity also is so small that ordinary sedimentation is not possible.

It is necessary, therefore, to use procedure which agglomerates the small particles into larger aggregates, which have practical settling velocities.

The term " Coagulation" and "flocculation" have been used indiscriminately to describe process of turbidity removal. "Coagulation" means to bring together the suspended particles. The process describes the effect produced by the addition of a chemical Alg (SP)g to a colloidal dispersion resulting in particle destabilization by a reduction of force tending to keep particles apart. Rapid mixing is important at this stage to obtain uniform dispersion of the chemical and to increase opportunity for particles to particle contact. This operation is done by flash mixer in the clarifloculator. Second stage of formation of settle able particles from destabilized colloidal sized particles is termed a "flocculation". Here coagulated particles grow in size by attaching to each other. In contrast to coagulation where the primary force is electrostatic or inter-ionic, "flocculation" occurs by chemical bridging. Flocculation is obtained by gentle and prolonged mixing which converts the submicroscopic coagulated particle into discrete, visible & suspended particles. At this stage particles are large enough to settle rapidly under the influence of gravity and may be removed.


RAW WATER
AERATOR
FLASH MIXER
CLARIFIER
CLARIFIED WATER STORAGE TANK
CLARIFIED WATER PUMPS
ANTHRACITE FILTER
ACTIVATED CARBON FILTER
CATION EXCHANGER
Air Degasser
DEGASSED WATER STORAGE TANK
ANION EXCHANGER
MIXED BED EXCHANGER
D.M. WATER

If pretreatment of the water is not done efficiently then consequences are as follows :

- SiOg may escape with water which will increase the anion loading.
- Organic matter may escape which may cause organic fouling in the anion exchanger beds. In the pre-treatment plant chlorine addition provision is normally made to combat organic contamination.
- Cation loading may unnecessary increase due to addition of Ca (OH)g in excess of calculated amount for raising the pH of the water for maximum floe formation and also AKOrDg may precipitate out. If less than calculated amount of Ca(OH), is added, proper pH floculation will not be obtained and silica escape to deminerahsation section will occur, thereby increasing load on anion bed.

Demineralisation

This filter water is now used for demineralising purpose and is fed to cation exchanger bed, but enroute being first dechlorinated, which is either done by passing through activated carbon filter or injecting along the flow of water, an equivalent amount of sodium sulphite through some stroke pumps. The residual chlorine which is maintained in clarification plant to remove organic matter from raw water is now detrimental to cation resin and must be eliminated before its entry to this bed.

Normally, the typical scheme of demineralisation upto the mark against an average surface water, is three bed system with a provision of removing gaseous carbon dioxide from water before feeding to Anion Exchanger. Now, let us see, What happens actually in each bed when water is passed from one to another.

Resins, which are built on synthetic matrix of a styrene divinely benzene copolymer, are manufactured in such a way that these have the ability to exchange one ion for another, hold it temporarily in chemical combination and give it to a strong electrolytic solution. Suitable treatment is a so given to them in such a way that a particular resin absorbs only a particular group of ions. Resins, when absorbing and releasing cationic portionof dissolved salts, is called cation, exchanger resin and when removing anionic portion is called anion exchanger resin.

The present trend is of employing strongly acidic cation exchanger resin and strongly basic anion exchanger resin in a DM Plant of modern thermal power station. We may see that the chemically active group in a cationic resin is SOx-H (normally represented by RH) and in an anionic resin the active group is either tertiary amine or quanternary ammonium group (normally the resin is represented by ROH).
The water from the ex-cation contains carbonic acid also sufficiently, which is very weak acid difficult to be removed by strongly basic anion resin and causing hindrance to remove silicate ions from the bed. It is therefore a usual practice to remove carbonic acid before it is led to anion exchanger bed. The ex-cation water is trickled in fine streams from top of a tall tower packed with rasching rings, and compressed air is passed from the bottom. Carbonic acid break into CO and water mechanically (Henry's Law) with the carbon dioxide escaping into the atmosphere. The water is accumulated in suitable storage tank below the tower, called degassed water dump, from where the same is led to anion exchanger bed, using acid resistant pump.
The ex-anion water is fed to the mixed bed exchanger containing both cationic resin and anionic resin. This bed not only takes care of sodium slip from cation but also silica slip from anion exchanger very effectively. The final output from the mixed bed is an extra-ordinarily pure water having less than 0.2/Mho conductivity, H 7.0 and silica content less than 0.02 ppm. Any deviation from the above quality means that the resins in mixed bed are exhausted and need regeneration, regeneration of the mixed bed first calls for suitable back washing and settling, so that the two types of resins are separated from each other. Lighter anion resin rises to the top and the heavier cation resin settles to the bottom. Both the resins are then regenerated separately with alkali and acid, rinsed to the desired value and air mixed, to mix the resin again thoroughly. It is then put to final rinsing till the desired quality is obtained.

It may be mentioned here that there are two types of strongly basic anion exchanger. Type II resins are slightly less basic than type I, but has a higher regeneration efficiency than type I. Again as type II resins are unable to remove silica effectively, type I resins also have to be used for the purpose. As such, the general condition so far prevailing in India, is to employ type II resin in anion exchangers bed and type I resin in mixed bed (for_the anionic portion). It is also a general convention to regenerate the above two resins under through fare system i.e. the caustic soda entering into mixed bed for regeneration, of type I anion resin, is utilised to regenerate type type II resin in anion exchanger bed. The concept of utilising the above resin and mode of regeneration is now a days being switched over from the economy to a more higher cost so as to have more stringent quality control of the final D.M. Water.

Internal Treatment

This final D.M effluent is then either led to hot well of the condenser directly as make up to boilers, or being stored in D.M. Water storage tanks first and then pumped for make up purpose to boiler feed.

As the D.M.Water has a good affinity to absorb carbon dioxide and oxygen, and both are extremely harmful to metal surfaces for their destruction like corrosion, these have to be removed before it is fed to boiler. This is being done in deaerator. Still the residual oxygen which is remaining in the water is neutralised by a suitable doze of hydrazine, at the point after deaerator. To have further minimum corrosion, the pH of feed water is to be maintained at around 9.0 for which purpose ammonia in suitable doze is added to this make up water at a point alongwith hydrazine as stated above.

Compressed Air System

Introduction

Instrument air is required for operating various dampers, burner tilting, devices, diaphragm valves etc., in the 210 MW Units. Station air meets the general requirement of the power station such as light oil atomising air, for cleaning filters and for various maintenance works. There are two types of compressed air system existing in a Thermal Power Station. They are Instrument Air System or control air system and Station Air System.
The control air compressors and station air compressors have been housed separately with separate receivers and supply headers and their tappings.

Control Air System

Control air compressors have been installed for supplying moisture free dry air required for instrument used. The output from the compressors is fed to air receivers via non return valves. From the receiver air is passed through the dryers to the main instrument air line which runs along with the boiler house and turbine house of 210 MW unit. Adequate number of tappings have been provided all over the area.

There is one interconnection between service air and instrument air headers just at the inlet of air drying units. This connection has been provided as an emergency provision to meet the requirement of instrument air in case of non-availability of instrument Air Compressor. The line connecting the service air header with instrument air header is provided with two isolating valves, one oil separator, one activated carbon filter, one non return valve and one regulating valve. Oil and dust free air is supplied to the instrument air header which is then passed through air drier units.

Instrument air compressors are of the double acting horizontal cross head type of two opposed cylinder. The compressors are driven by electric motor through V belts. Gear wheel type lubricating oil pump is provided to feed the main bearing. connecting rod bearing and cross heads of one side, i.e. to the opposite side of the crank shaft rotation piston. The cylinders ar e self-lubricated as they are fitted with teflon rings. Plate type valves are provided at suction and delivery. The compressor is equipped with water cooled inter cooler or header, pressure regulator to load and unload the compressor and safety valves for first and second stages. The suction air filter is at the middle of the cylinder so that air can enter at both ends of the piston. After compression the air passes through the delivery valves to the Inter-cooler where the air is considerably cooled and enters the H.P. cylinder. The entrapped air in HP side is compressed in a similar manner as in L.P. Cyinder to the required pressure and enters the header connected to the H.P. cylinders through the delivery valves and then finally to the air receiver.

Air-Drying Unit:

Air contains moisture which tends to condense, and causes trouble in operation of various devices by compressed air. Therefore drying of air is accepted widely in case of instrument air. Air drying unit consists of dual absorption towers with embedded heaters for reactivation. The absorption towers are adequately filled with specially selected silica gel and activated alumina. While one tower is drying the air, the other tower is under recativation. Thus, the unit maintains continuous supply of dry air for plant requirement. This system is completely automatic.

Service- Air Compressor :

The station air compressor is generally a slow speed horizontal double acting double stage type and is arranged for belt drive. The cylinder heads and barrel are enclosed in a jacket which extends around the valve also. The inter cooler is provided between the low and high pressure cylinder which cools the air between stage and collects the moisture that condenses.

Air from L.P. Cylinder enters at one end of the inter cooler and goes to the opposite end wherefrom it is discharged to the high pressure cylinder, cooling water flows through the nest of tubes and cools the air. A safety valve is set at rated pressure.

From the high pressure cylinder compr essed air is led through water cooled " after cooler" which is provided with inlet and outlet water connection and a drain. The "after cooler" cools the compressed air, condensing the water vapour. A moisture separator with a drain trap and a filter are pr ovided to remove moisture and dust particles from the compressed air. The air is then led to the air receiver via a non-return valve. The receiver is located out side the compressor house. Receiver is provided with a pressure gauges safety valve and drain valve.

Two selector switches one with positions Auto load/unload and Auto unload and another with positions Auto start-stop, non-stop have been provided on the control panel of the compressor. In auto-start-stop position the compressor will start when the receiver pressure drops down to 'Cut in' pressure and will stop when the receiver reaches the 'cut out' pressure.