Chapter 1

STEAM POWER PLANT

1.1. INTRODUCTION: A Generating station which converts heat energy of coal combustion into electrical energy is known as steam power station. A steam power station basically works on Rankin cycle. Steam is produced in the boiler by utilizing the heat of coal combustion or burning gases or fuel.

Fig 1-1: Diagram of a steam power plant

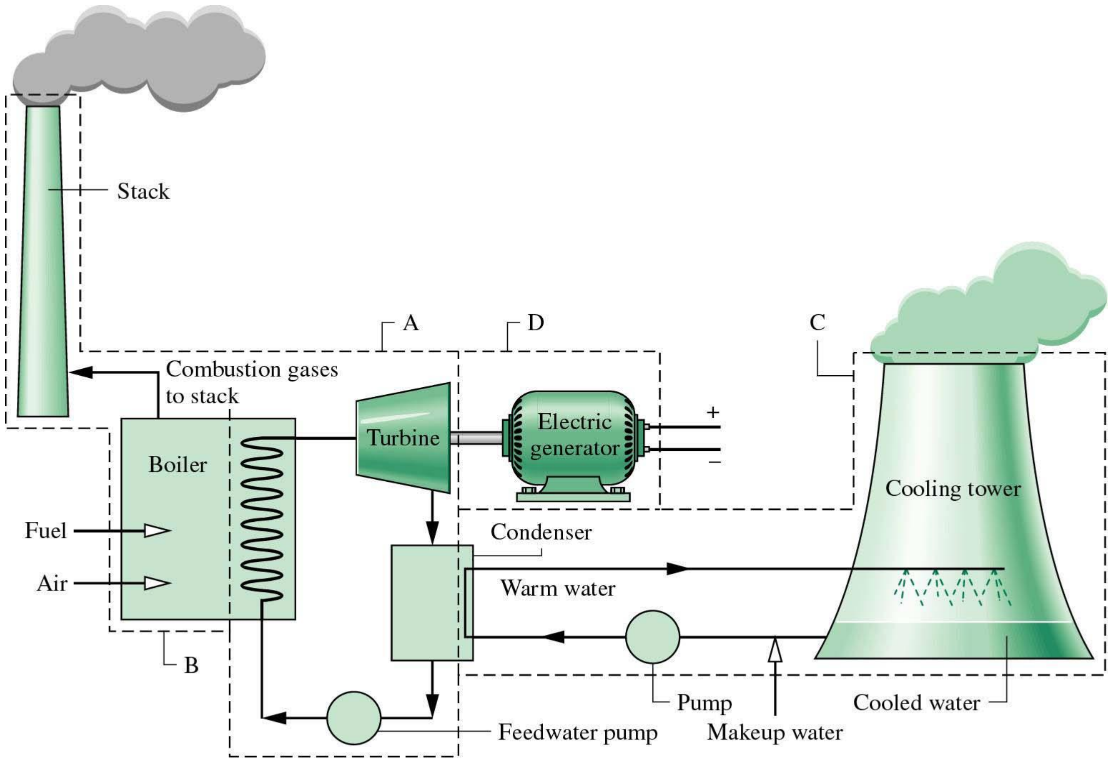

Fig 1-2: Block diagram of a steam power plante

1.2. Power plants:

Modern-day boilers, such as those in coal-fired power stations, are still fitted with economizers which are descendants of Green's original design. In this context they are often referred to as feed water heaters and heat the condensate from turbines before it is pumped to the boilers.

Economizers are commonly used as part of a heat recovery steam generator in a combined cycle power plant. In an HRSG, water passes through an economizer, then a boiler and then a super heater. The economizer also prevents flooding of the boiler with liquid water that is too cold to be boiled given the flow rates and design of the boiler.

A common application of economizers in steam power plants is to capture the waster heat from boiler stack gases (flue gas) and transfer it to the boiler feed water. This raises the temperature of the boiler feed water thus lowering the needed energy input, in turn reducing the firing rates to accomplish the rated boiler output. Economizers lower stack temperatures which may cause condensation of acidic combustion gases and serious equipment corrosion damage if care is not taken in their design and material selection

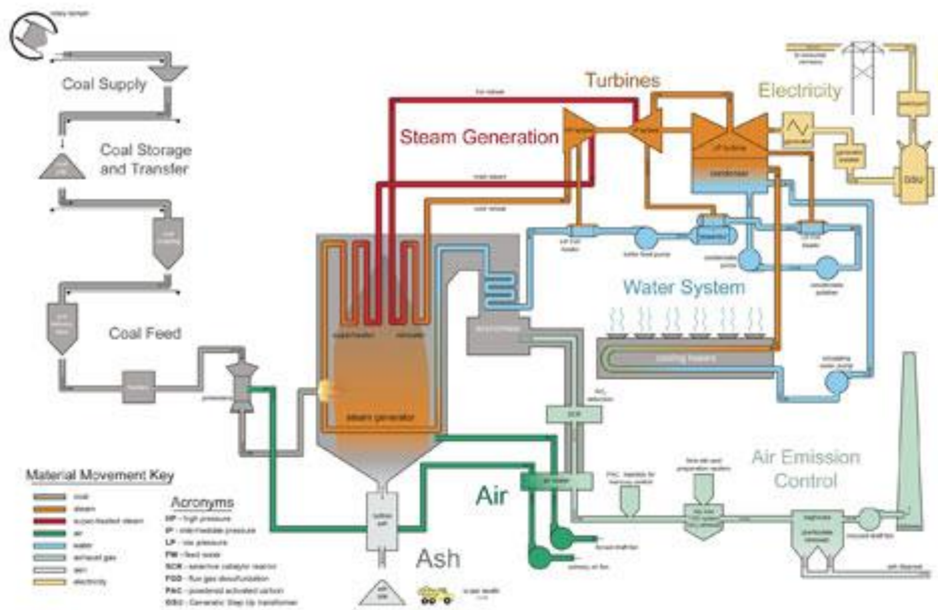

Fig 1-3: Block diagram of a steam power plant

Elements of steam power plant:

01. Boiler

02. Turbine

03. Generator

1.3. Field of Application:

1.3.1. Private industrial plants: Industries which require steam for process purposes may sometimes use steam turbine for power production also, so that the electric power required by the industry can be supplied from the steam turbine sets. The back pressure turbines can exhaust steam at constant pressure, as for evaporator supply, or at varying pressure, as for heating purposes. Industrial turbo generators are of capacities up to 10MW. The steam for process purposes may be tapped from extraction bleeding of the turbines at a pressure of 1.4 to 7 kg/cm^2. The mechanics are either 4 poles or 2poles. In some times speed reduction gearing is required between the turbine and generator.

1.3.2. Central station: steam stations are mainly used as central stations to produce electric power for supply under takings. In these stations, the a.c. generators are driven by turbines with condensing arrangements at high vacuum of about 73.6 cm Hg.

1.4. Steam Plant Operation:

For each plant operation, there is an optimum method of treatment. Many factors are involved in proper selection of feed water preparation and internal treatment. Principally, these are the requirements of the plant for safe and reliable operation at an economical treating cost.

1.5. Main parts and working of a steam station:

The main parts of a steam station are the boiler or steam generator, the steam turbine, and the electric generator which is coupled to it. The fuel is burned and the heat in the fuel is used in the boiler to convert water into steam at required pressure and temperature. The steam is supplied to the turbine, where it's expansion produces mechanical power at the turbine shaft. This power is used to drive the generator, which in turn produces electric power.

Chapter 2

BOILER

2.1. Boiler: A steam boiler is usually a closed vessel made of steal. Its function is to transfer the heat produced by the common of fuel to water, and ultimately to generate steam. The steam produced may be supplied.

1. to an external combustion engine.
2. at low pressure for industrial process work
3. for producing hot water.

2.1.1. Boilers:

In boilers, economizers are heat exchange devices that heat fluids, usually water, up to but not normally beyond the boiling point of that fluid. Economizers are so named because they can make use of the enthalpy in fluid streams that are hot, but not hot enough to be used in a boiler, thereby recovering more useful enthalpy and improving the boiler's efficiency. They are a device fitted to a boiler which saves energy by using the exhaust gases from the boiler to preheat the cold water used to fill it (the feed water).

2.2. History:

The first successful design of economizer was used to increase the steam-raising efficiency of the boilers of stationary steam engines. It was patented by Edward Green in 1845, and since then has been known as Green's economizer. It consisted of an array of vertical cast iron tubes connected to a tank of water above and below, between which the boilers exhaust gases passed. This is the reverse arrangement to that of fire tubes in a boiler itself; there the hot gases pass through tubes immersed in water, whereas in an economizer the water passes through tubes surrounded by hot gases. The most successful feature of Green's design of economizer was its mechanical scraping apparatus, which was needed to keep the tubes free of deposits of soot.

2.3. Classification of steam boilers:

Though there are many classifications of steam boilers,

01. According to the contents in the tube: The steam boilers, according to the contents in the tube may be classified as

a) Fire tube or smoke tube boiler   b) Water tube boiler

In fire tube boilers, the flames and hot gases, produced by the combustion of fuel, pass through the tubes which are surrounded by water. The heat is conducted through the walls of the tubes from the hot gases to the surrounded water.

In water tube steam boilers, the water is contained inside the tubes which are surrounded by the flames and hot gases from outside.

02. According to the position of the furnace: The steam boilers, according to the position of the furnace may be classified as:

a) Internally fired boilers b) Externally fired boilers

In Internally fired boilers, the furnace is located inside the boiler shell. Most of the fire tube steam boilers are internally fired.

In Externally fired boilers, the furnace is arranged underneath is a break-work setting. Water tube boilers are always externally fired boilers.

03. According to the axis of the shell: The steam boilers, according to the axis of the shell may be classified as:

a) Vertical boilers b) Horizontal boilers

In Vertical steam boilers, the axis of the shell is Vertical.

In Horizontal boilers, the axis of the shell is Horizontal.

04. According to the number of tubes: The steam boilers, according to the number of tubes may be classified as:

a) Single tube boilers b) Multi tube boilers

In Single tube steam boilers, there is only one fire tube or water tube.

In multi tube steam boilers, there are two or more fire tubes or water tube.

05. According to the method of circulation of water and steam: The steam boilers, according to the method of circulation of water and steam may be classified as:

a) Natural circulation boilers, b) Forced circulation boilers

In Natural circulation steam boilers, the circulation of water is by natural convection currents, which are set up during the heating of water. In most of the steam boilers, there is a natural circulation of water.

In Forced circulation steam boilers, there is a Forced circulation of water by a centrifugal pump driven by some external power. Use of Forced circulation is made of high pressure.

06. According to the use: The steam boilers, according to their use, may be classified as:

a) Stationary boilers, b) Mobile boilers

The stationary steam boilers are used in power plants, and in industrial process work. These are called stationary because they do not move from one place to another.

The Mobile steam boilers are used in locomotive and marine boilers. These are called Mobile because they can move from one place to another.

07. According to the source of heat: The steam boilers, according to the source of heat supplied for producing steam. These sources may be combustion of solid, liquid or gaseous fuel, electrical energy or nuclear energy.

2.4. Important terms for steam boilers:

There are many terms used in steam boilers, yet the following are important from the subject point of view

Boiler shell: It is made up of steel plates bent into cylindrical form and riveted or welded together. The ends of the shell are closed by means of end plates. A boiler shell should have sufficient capacity to contain water and steam.

Combustion chamber: It ids the space, generally below the boiler shell, meant for burning fuel in order to produce steam from the water contained in the shell.

Grate: It is a platform, in the combustion chamber, upon which fuel in burnt. The grate, generally, consist of cast iron bars which are spaced apart so that air can pass through them. The surface area of the grate, over which the fire takes place, is called grade surface.

Furnace: It is the space, above the grate and below the boiler shell, in which the fuel is actually burnt. The furnace is also called fire box.

Heating surface: It is that part of boiler surface which is exposed to the fire.

Mountings: These are the fittings which are mounted on the boiler for its proper functioning. The include water level indicator, pressure gauge, safety valve etc.

Accessories: These are the devices which form an integral part of a boiler, but are not mounted on it. They include super heater, feed pump etc.

2.5. Essenentials of a good steam boiler:

01. It should produce maximum quantity of steam with the minimum fuel consumption.

02. It should be economical to install, and should require little attention during operation.

03. It should rapidly meet the fluctuation of load.

04. It should capable of quick starting.

05. It should occupy a small space.

06. The joints should be few and accessible for inspection.

07. It should be light in weight.

2.6. Selection of a steam Boiler:

The power required and the working pressure.

0.1 The rate at which steam is to be generated.

0.2 The geographical position of the power house.

0.3 The fuel and water available.

0.4 The type of fuel to be used.

0.5 The probable permanency of the station.

0.6 The probable load factor.

Chapter 3

Operation of Boilers

3.1. Role of Boilers in Plant Operation (Steam Generation):

A boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. In the boiler furnace, the chemical energy in the fuel is converted into heat, and it is the function of the boiler to transfer this heat to the contained water in the most efficient manner. The boiler should also be designed to generate high quality steam for plant use. A flow diagram for a typical boiler plant is presented in Figure 12.l.

A boiler must be designed to absorb the maximum amount of heat released in the process of combustion. This heat is transferred to the boiler water through radiation, conduction and convection. The relative percentage of each is dependent upon the type of boiler, the designed heat transfer surface and the fuels.

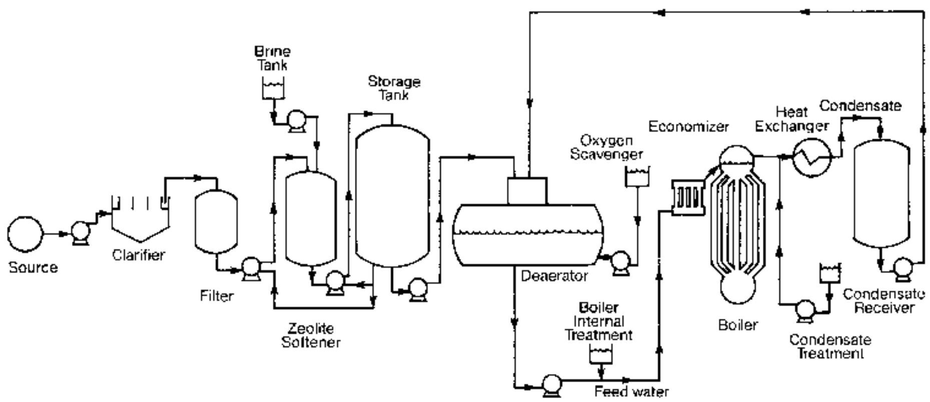

Fig 3-1: Boiler Plant Flow Diagram

3.2. BOILER MOUNTINGS AND ACCESSORIES:

Boiler Mountings: These are the fittings, which are mounted on the boiler for its proper and safe functioning. Though there are many types of boiler Mountings, yet the following are important from the subject point of view:

01. Water level indicator;

02. Pressure gauge;

03. Safety valves;

04. Stop valve;

05. Blow off clock;

06. Feed check valve; and

07. Fusible plug.

01. Water level indicator: It is an important fitting, which indicates the water level inside the boiler to an observer. It is a safe device, upon which the correct working of the boiler depends. This fitting may be seen in front of the boiler, and are generally two in number.

02. Pressure gauge: A Pressure gauge is used to measure the pressure of the steam inside the steam boiler. It is fixed in front of the steam boiler. The Pressure gauge generally used is of Bourden type.

03. Safety valves: These are the devices attached to the steam chest for preventing explosions due to excessive internal pressure of steam. A steam boiler is, usually, provided with two safety valves. These are directly placed on the boiler. In brief, the function of a safety valve is to blow off the steam when the pressure of steam inside the boiler exceeds the working pressure. The following are the four types of safety valves:

a) Lever safety valve, c) High steam and low water safety valve,
b) Dead weight safety valve, d) Spring loaded safety valve,

It may be noted that the first three types of the safety valves are usually employed with stationary boilers, but the fourth type is mainly used for locomotive and marine boilers.

04. Stop valve: It is the largest valve on the steam boiler. It is usually fitted to the highest part of the
Shell by means of a flange. The principal function of a stop valve is:

a) To control the flow of steam from the boiler to the main steam pipe.
b) To shut off the steam completely when required.

The body of the stop valve is made of cast iron or cast steal. The valve, valve seat and the nut through which the valve spindle works are made of brass or gun metal.

05. Blow off clock: The principal functions of a blow off cock are:

1) To empty the boiler whenever required.
2) To discharge the mud, scale or sediments which are accumulated at the bottom of the boiler.

06. Feed check valve: It is a non return valve, fitted to a screwed spindle to regulate the lift. Its function is to regulate the supply of water, which is pumped into the boiler, by the feed pump. This valve must have its spindle lifted before the pump is started. It is fitted to the shell slightly below the normal water level of the boiler.

07. Fusible plug: It gs fitted to the crown plate of the furnace or the fire. Its object gs to put off the fire in the furnace of the boiler when the level of water in the boiler falls to an unsafe limit, and thus avoids the explosion which may take place due to overheating of the furnace plate. A fusible plug must not be refilled with anything except fusible metal.

3.3. Boiler accessories:

Thease are the devices which are used as integral parts of a boiler, and help in running efficiently. Though there are many types of boiler accessories, yet the following are important from the subject point of view:

1. Feed pump;
2. Superheater;
3. Economiser; and
4. Air preheater

01. Feed pump:

We know that water, in a boiler, is continuously converted into steam, which is used by the engine. Thus we need feed pump to deliver water to the boiler.

The pressure of steam inside a boiler is high. So the pressure of feed water has to be increased proportionately before it is made to enter the boiler. Generally, the pressure of feed water is 20% more than that in the boiler.

A feed pump may be of centrifugal type or reciprocating type. But a double acting reciprocating pump is commonly used as a feed pump thease days. The reciprocating pumps are run by the steam from the same boiler in which water is to be fed.

02. Superheater:

Fig 3-2: A superheated boiler on a steam locomotive.

Fossil fuel power plants can have a super heater and/or reheater section in the steam generating furnace. Nuclear-powered steam plants do not have such sections but produce steam at essentially saturated conditions. In a fossil fuel plant, after the steam is conditioned by the drying equipment inside the steam drum, it is piped from the upper drum area into tubes inside an area of the furnace known as the super heater, which has an elaborate set up of tubing where the steam vapor picks up more energy from hot flue gases outside the tubing and its temperature is now superheated above the saturation temperature. The superheated steam is then piped through the main steam lines to the valves before the high pressure turbine.

03. Economiser:

An Economiser is a device used to feed water by utilising the heat in the exhaust flue gases before leaving the chimney. As the name indicates, the economizer improves the economy of the steam boiler.

A well known type of economizer is Greens Economizer. It is extensively

Used for stationary boilers, especially those of Lancashire type. It consists of a large number of vertical pipes or tubes.placed in an enlargement of the flue gases between the boiler and the Chimney. These tubes are 2.75 meters long.114 mm in external diameter and 11.5 mm thick and are made of cast iron.

The economizer is built up transverse section. Each section consists of six or eight vertical tubes. These tubes are joined together to horizontal tubes or boxes and at the top and bottom respectively. The top boxes of the different sections are connected to the pipe. The pipes are on the opposite sides, which are out side the brickwork enclosing the Economiser.

The feed water is pumped into the economizer at and enters the pipe. Then it passes into bottom boxes and then into the top boxes through tubes It is now led by the pipe to pipe and then to the Boiler. There is a blow off cock at the end of pipe opposite to the feed inlets. The purpose of this valve is to remove mud or sediment deposited in the bottom boxes. At the end of pipe (opposite to the feed outlets) the is a safety valve.

It is essential the vertical tubes may be kept free deposit of soot, which greatly reduce the efficiency of the economizer. Each tube is provided with scraper for this purpose.

04. Air preheater:

An Air preheater is used to recover heat from the exhaust flue gases. It is installed between the economizer and the chimney. The air required for the purpose of combustion is drawn through the air preheater where its temperature is raised.

The following are obtained by using an air preheater:

01. The preheated air gives higher furnace temperature which results in more heat transfer to the water and thus increases the evaporative capacity per kg of fuel.

02. There is an increase of about 2% in the boiler efficiency for each 35-40 º C rise in temperature of air.

03. It results in better combustion with less soot, smoke and ash.

04. It enables a low grade fuel to be burnt with less excess air.

3.4. Utilization:

The boiler house or steam generation facility within any given plant is frequently referred to as the heart. In the event this system shuts down for unexpected reasons or for plant turnaround, most processes within the plant will not be operable. For this reason, very conservative treatment measures are used in the boiler. Operating personnel can be reluctant to change treatment programs if the one currently in use is deemed successful. On the other hand, if a treatment program is linked to a boiler failure, change usually comes quickly.

3.4.1. Steam Utilization:

Steam is generated for the following plant uses:

1. Turbine drive for electric generating equipment, blowers and pumps

2. Process for direct contact with products, direct contact sterilization and noncontact for processing temperatures

3. Heating and air conditioning for comfort and equipment

The efficiency achievable with steam generation relies heavily on the system's ability to return condensed steam to the operating cycle. Many of the systems described above return a significant portion of the condensed steam to the generation cycle.

3.5. The Role of Water Treatment in Steam Generation:

Based on an operating history that exceeds 50 years, the American Society of Mechanical Engineers (ASME) has provided guidelines for water quality in modern industrial boilers. These criteria were established to assure reliable and safe operation of boilers.

3.5.1. External Treatment:

External treatment, as the term is applied to water prepared for use as boiler feed water, usually refers to the chemical and mechanical treatment of the water source. The goal is to improve the quality of this source prior to its use as boiler feed water, external to the operating boiler itself. Such external treatment normally includes:

1. Clarification
2. Filtration
3. Softening
4. Dealkalization
5. Demineralization
6. Deaeration

3.5.2. Internal Treatment:

Even after the best and most appropriate external treatment of the water source, boiler feed water (including return condensate) still contains impurities that could adversely affect boiler operation. Internal boiler water treatment is then applied to minimize the potential problems and to avoid any catastrophic failure, regardless of external treatment malfunction.

3.6. Deaerators:

Mechanical deaeration is the first step in eliminating oxygen and other corrosive gases from the feed water. Free carbon dioxide is also removed by deaeration, while combined carbon dioxide is released with the steam in the boiler and subsequently dissolves in the condensate. This can cause additional corrosion problems.

Because dissolved oxygen is a constant threat to boiler tube integrity, our discussion on the deaerator will be aimed at reducing the oxygen content of the feed water. The two major types of deaerators are the tray type and the spray type. In both cases, the major portion of gas removal is accomplished by spraying cold makeup water into a steam environment.

3.6.1. Tray-Type Deaerating Heaters:

Tray-type deaerating heaters release dissolved gases in the incoming water by reducing it to a fine spray as it cascades over several rows of trays. The steam that makes intimate contact with the water droplets then scrubs the dissolved gases by its counter-current flow. The steam heats the water to within 3-5 º F of the steam saturation temperature and it should remove all but the very last traces of oxygen. The deaerated water then falls to the storage space below, where a steam blanket protects it from recontamination.

Nozzles and trays should be inspected regularly to insure that they are free of deposits and are in their proper position.

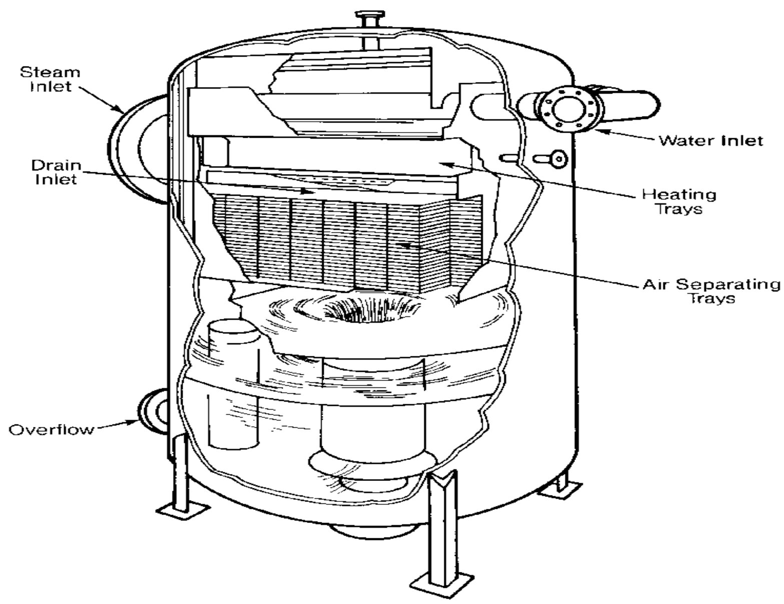

Fig 3-3: Tray-Type Deaerating Heater (Cochrane Corp.)

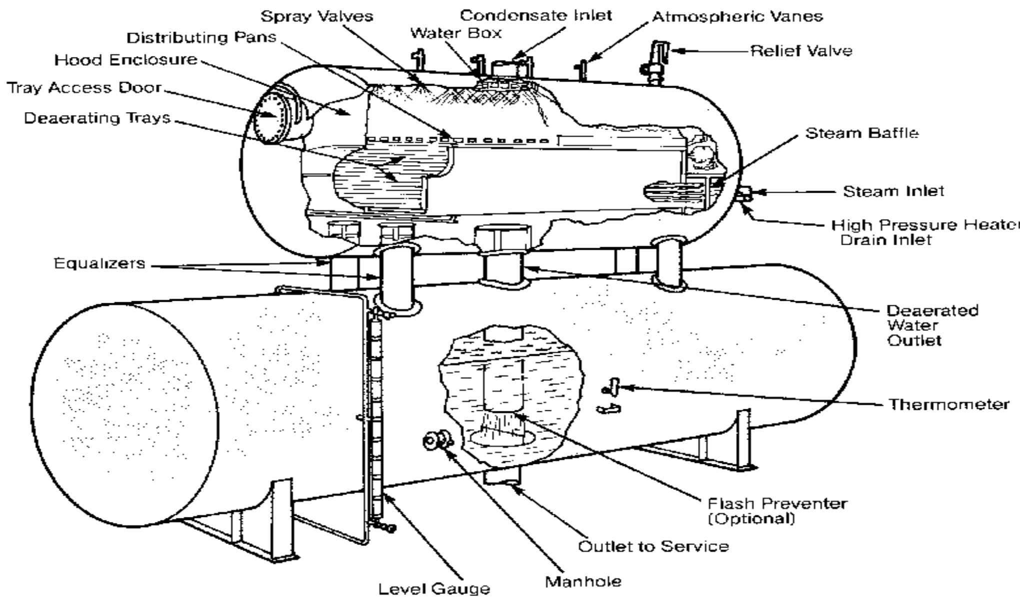

Fig 3-4: Tray-Type Deaerating Heater (Graver)

3.7. Condenser and Cooling Tower:

Condensing steam power plants have better thermal efficiency, hence if steam is not required for any process it is desirable to condense steam back into water and recycle the water back into boiler. Usually a surface condenser is used to condense the steam exhausted from turbine. Steam condensing must take place under deep vacuum condition. The reason for it is two fold. One, if the air is present in the condenser it prevents the steam contact with condenser tubes because the air is already occupying the space, hence the surface condenser will not operate properly if there is air in it.

Secondly, if the steam is expanded, via turbine, into deep vacuum more power is extracted from each pound of steam. It is desirable to hold the vacuum at minimum of 28.5 inches of mercury. If there is enough cooling water of low temperature it is easy to reach 29.5 inches vacuum. The theoretical 30 inches of vacuum is impossible to reach, therefore, 29.5 inches is very good vacuum. Steam driven two stage air ejector is constantly operated to keep ahead of infiltrating air leaking into the condenser system.

Surface condenser ejects a massive amount of low grade heat; therefore, a lot of cooling water is required. The steam temperature entering the condenser under 29 inches of vacuum is about 100 degrees F, however, the enthalpy (heat content) of steam is still over 1,000 BTU per pound, hence you can see that a huge amount of heat must be ejected into cooling water. For example: If the turbine uses 20,000 pounds of steam per 1Mw / per hour (modern and large turbines use less steam, some below 10,000 lb per 1Mw/h), it means that over 20 million BTU of heat energy must be ejected into cooling water.

The most common method of providing cooling water for condenser is to recirculate cooling water via cooling tower where the recirculating water is cooled by evaporation and air contact. In our installation we use a refrigeration type cooling tower. This cooling tower is of compact round design with rotary water distribution over the evaporative surface. Motor driven cooling fan of 10 feet diameter is used to provide air movement through the cooling tower. Water recirculation is at 1,400 gallons per minute. The power consumption for air fan and recirculation pump is only 15 Hp. This is very efficient, due to low height difference between condensers and cooling tower discharge, therefore, the pump doesn't have to lift water too high, resulting in power savings.

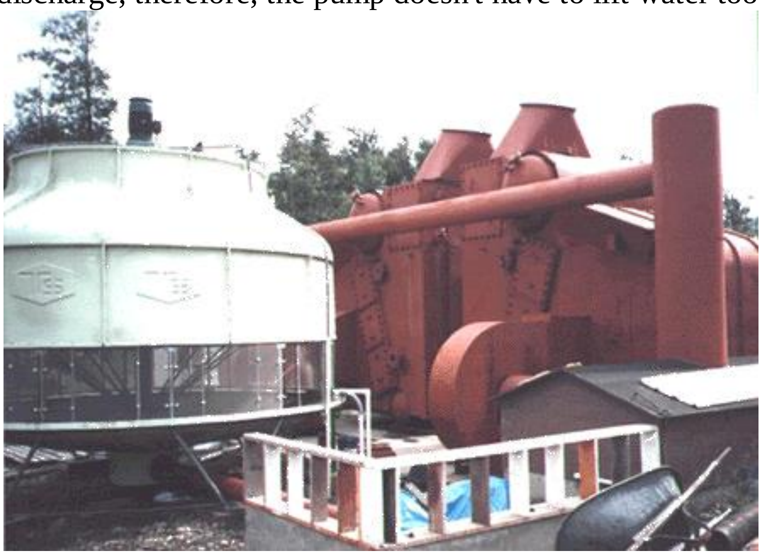

Fig 3-5: Cooling Tower

3.8. Boiler furnace and steam drum:

Once water inside the boiler or steam generator, the process of adding the latent heat of vaporization or enthalpy is underway. The boiler transfers energy to the water by the chemical reaction of burning some type of fuel.

The water enters the boiler through a section in the convection pass called the economizer. From the economizer it passes to the steam drum. Once the water enters the steam drum it goes down the downcomers to the lower inlet waterfall headers. From the inlet headers the water rises through the water walls and is eventually turned into steam due to the heat being generated by the burners located on the front and rear waterfalls (typically). As the water is turned into steam/vapor in the water walls, the steam/vapor once again enters the steam drum. The steam/vapor is passed through a series of steam and water separators and then dryers inside the steam drum. The steam separators and dryers remove water droplets from the steam and the cycle through the waterfalls is repeated. This process is known as natural circulation.

The boiler furnace auxiliary equipment includes coal feed nozzles and igniter guns, soot blowers, water lancing and observation ports (in the furnace walls) for observation of the furnace interior. Furnace explosions due to any accumulation of combustible gases after a trip-out are avoided by flushing out such gases from the combustion zone before igniting the coal.

The steam drum (as well as the super heater coils and headers) have air vents and drains needed for initial startup. The steam drum has internal devices that removes moisture from the wet steam entering the drum from the steam generating tubes. The dry steam then flows into the super heater coils.

3.9. Fuel preparation system:

In coal-fired power stations, the raw feed coal from the coal storage area is first crushed into small pieces and then conveyed to the coal feed hoppers at the boilers. The coal is next pulverized into a very fine powder. The pulverizers may be ball mills, rotating drum grinders, or other types of grinders.

Some power stations burn fuel oil rather than coal. The oil must kept warm (above its pour point) in the fuel oil storage tanks to prevent the oil from congealing and becoming unpumpable. The oil is usually heated to about 100°C before being pumped through the furnace fuel oil spray nozzles.

Boilers in some power stations use processed natural gas as their main fuel. Other power stations may use processed natural gas as auxiliary fuel in the event that their main fuel supply (coal or oil) is interrupted. In such cases, separate gas burners are provided on the boiler furnaces.

3.10. Condenser:

The surface condenser is a shell and tube heat exchanger in which cooling water is circulated through the tubes. The exhaust steam from the low pressure turbine enters the shell where it is cooled and converted to condensate (water) by flowing over the tubes as shown in the adjacent diagram. Such condensers use steam ejectors or rotary motor-driven exhausters for continuous removal of air and gases from the steam side to maintain vacuum.

For best efficiency, the temperature in the condenser must be kept as low as practical in order to achieve the lowest possible pressure in the condensing steam. Since the condenser temperature can almost always be kept significantly below 100 ^{o}C where the vapor pressure of water is much less than atmospheric pressure, the condenser generally works under vacuum. Thus leaks of non-condensable air into the closed loop must be prevented. Plants operating in hot climates may have to reduce output if their source of condenser cooling water becomes warmer; unfortunately this usually coincides with periods of high electrical demand for air conditioning.

The condenser generally uses either circulating cooling water from a cooling tower to reject waste heat to the atmosphere, or once-through water from a river, lake or ocean.

3.11. Feed water heater:

In the case of a conventional steam-electric power plant utilizing a drum boiler, the surface condenser removes the latent heat of vaporization from the steam as it changes states from vapors to liquid. The heat content (btu) in the steam is referred to as Enthalpy. The condensate pump then pumps the condensate water through a feed water heater. The feed water heating equipment then raises the temperature of the water by utilizing extraction steam from various stages of the turbine.[2][3]

Preheating the feed water reduces the irreversibilities involved in steam generation and therefore improves the thermodynamic efficiency of the system.[9] This reduces plant operating costs and also helps to avoid thermal shock to the boiler metal when the feed water is introduced back into the steam cycle.

3.12. Boiler Waterside Corrosion:

The most significant contributors to boiler waterside corrosion are dissolved oxygen, acid or caustic in the water and a high temperature. If any of these are uncontrolled, severe pitting, gouging and embrittling of the tube metal can occur, which will ultimately lead to failure. A good understanding of the mechanisms and control of these factors is extremely important.

3.12.1. Why Some Corrosion in the Boiler is Necessary:

Water will rapidly corrode mild steel; as the temperature increases, the reaction accelerates. The following reaction is typical of iron corrosion in a boiler:

3 Fe + $4H_20$ » Fe_3O_4 + $4H_2$

Iron + Water/Steam » Magnetite + Hydrogen gas

The magnetite produced is black iron oxide. Under normal operating conditions, this is the typical product of corrosion. However, it is also this reaction that inhibits excessive corrosion in steaming boilers. In a new or clean boiler, the initial corrosion process produces this magnetite film as a tenacious layer at the steel surface. This magnetite layer prevents any further contact with the steel or water surface. Consequently, the corrosion reaction is self-inhibiting.

This magnetite layer grows to an approximate thickness of 0.0004-0.001 inches, at which point any further corrosion process ceases. Periodic weakening or damaging of this protective shell does occur, and proper internal boiler water treatment can repair this layer. The normal corrosion in a clean boiler

3.12.2. Other Causes of Corrosion:

01. Dissolved Oxygen. In previous discussions concerning mechanical and chemical deaeration, removal of dissolved oxygen was considered essential. When dissolved oxygen enters the steaming boiler, corrosion manifests itself in the form of severe deep pits, almost exclusively at the water level in the steam drum. If oxygen attack has occurred, it is readily identifiable during inspection.

02. PH Variation (Acidic or Caustic Attack). A pH of 10.5-11.5 was identified as ideal for boiler operation, excluding high purity systems that could function on other types of treatment programs. Variations from the levels that are considered optimum for maintenance of the magnetite layer can cause general corrosion. Each of these will be discussed below.

03. Acidic Attack. If boiler water pH has dropped significantly below 8.5, a phenomenon called waterside thinning can occur. The normal manifestation of acidic attack is etching. In areas of higher flow, the surfaces are smooth. In addition, any stressed area would be a principal area for attack.

04. Caustic Attack. Caustic attack or, as it is more commonly known, caustic corrosion, is often encountered in phosphate treated boilers in which deposits occur in high heat transfer areas. In particular, boiler water can permeate the porous deposit. When it is coupled with significant heat flux, concentration of the boiler water occurs. Caustic soda (NaOH) is the only normal boiler water constituent that has high solubility and does not crystallize under

these circumstances. This caustic concentration can be as high as 10,000-100,000 ppm. Localized attack due to the extremely high pH (12.9 +) will occur, as will the formation of caustic-ferritic compounds through the dissolving of the protective magnetite film. Once the process begins, the iron in contact with the boiler water will attempt to restore the protective magnetite film. Caustic corrosion (typically in the form of gouging) continues until the deposit is removed or the caustic concentration is reduced to normal.

Caustic attack typically appears in the form of irregular patterns and gouges. Frequently, the white salts associated with caustic attack remain in the tube samples. In addition, if caustic attack has proceeded for any extended period of time, significant levels of magnetic iron oxide can be found in any low flow area, such as a mud drum. This is essentially "stripping" of the magnetite film.

05. Streamside Tracking. This form of corrosive attack generally occurs in lower temperature areas of the boiler. A series of factors may permit stratified flow of steam and water in a given tube. When stratification occurs, the velocity of the steam-water mixture is not sufficient to maintain turbulent flow as the steam-water mixtures passes through the tubes. The affected tubes normally reveal gouging at the steam-water line and thinning under any deposits that have accumulated. Usually these systems contain a certain amount of caustic, which aggravates the rate of attack.

The phenomenon does occur in higher heat transfer areas as a function of a direct action between steam and hot steel. Metal temperatures of 900 º F (482 ºC) are required for this type of attack to proceed. Similar results in the form of thinning and gouging will be in evidence; however, a metallurgical examination might be required to determine the true mechanism of attack.

Streamside tracking or blanketing is a direct corrosive attack, similar to the acid or caustic attack. The other normally encountered form of corrosion is stress-related corrosion.

06. Stress Attack. Metallurgical examinations are required to identify the causes of stress attack. On occasion, intergranular or transgranular attack can be seen on tube specimens. The intergranular or transgranular attack can be a function of system condition or boiler water chemistry. It generally occurs in higher pressure systems.

3.13. Conclusions:

- Proper corrosion control is a function of several factors.
- Proper boiler chemistry for operating pressures and conditions.
- Close scrutiny and control of boiler water chemistry.
- Frequent testing of boiler water chemistry.
- Thorough inspection of all waterside areas during shutdown.

Chapter 4

STEAM TURBINE:

4.1. Steam Turbine:

Fig4-1: A Siemens steam turbine with the case opened.

A turbine is a rotary engine that extracts energy from a fluid flow. Claude Burdin (1788-1873) coined the term from the Latin turbo, or vortex, during an 1828 engineering competition. Benoit Fourneyron (1802-1867), a student of Claude Burdin, built the first practical water turbine.

The simplest turbines have one moving part, a rotor assembly, which is a shaft with blades attached. Moving fluid acts on the blades, or the blades react to the flow, so that they rotate and impart energy to the rotor. Early turbine examples are windmills and water wheels.

Gas, steam, and water turbines usually have a casing around the blades that contains and controls the working fluid. Credit for invention of the modern steam turbine is given to British Engineer Sir Charles Parsons (1854 - 1931).

A device similar to a turbine but operating in reverse is a compressor or pump. The axial compressor in many gas turbine engines is a common example.

4.2. Types of turbines:

Steam turbines are used for the generation of electricity in thermal power plants, such as plants using coal or fuel oil or nuclear power. They were once used to directly drive mechanical devices such as ship's propellors (eg the Turbinia), but most such applications now use reduction gears or an intermediate electrical step, where the turbine is used to generate electricity, which then powers an electric motor connected to the mechanical load.

Gas turbines are sometimes referred to as turbine engines. Such engines usually feature an inlet, fan, compressor, combustor and nozzle (possibly other assemblies) in addition to one or more turbines.

4.2.1. Transonic turbine. The gasflow in most turbines employed in gas turbine engines remains subsonic throughout the expansion process. In a transonic turbine the gasflow becomes supersonic as it exits the nozzle guide vanes, although the downstream velocities normally become subsonic. Transonic turbines operate at a higher pressure ratio than normal but are usually less efficient and uncommon. This turbine works well in creating power from water.

4.1.2. Contra-rotating turbines. Some efficiency advantage can be obtained if a downstream turbine rotates in the opposite direction to an upstream unit. However, the complication may be counter-productive.

4.1.3. Stator less turbine. Multi-stage turbines have a set of static (meaning stationary) inlet guide vanes that direct the gasflow onto the rotating rotor blades. In a statorless turbine the gasflow exiting an upstream rotor impinges onto a downstream rotor without an intermediate set of stator vanes (that rearrange the pressure/velocity energy levels of the flow) being encountered.

4.1.4. Ceramic turbine. Conventional high-pressure turbine blades (and vanes) are made from nickel-steel alloys and often utilise intricate internal air-cooling passages to prevent the metal from melting. In recent years, experimental ceramic blades have been manufactured and tested in gas turbines, with a view to increasing Rotor Inlet Temperatures and/or, possibly, eliminating.

4.1.5. Air-cooling. Ceramic blades are more brittle than their metallic counterparts, and carry a greater risk of catastrophic blade failure.

4.1.6. Shrouded turbine. Many turbine rotor blades have a shroud at the top, which interlocks with that of adjacent blades, to increase damping and thereby reduce blade flutter.

4.1.7. Shroudless turbine. Modern practise is, where possible, to eliminate the rotor shroud, thus reducing the centrifugal load on the blade and the cooling requirements.

Bladeless turbine uses the boundary layer effect and not a fluid impinging upon the blades as in a conventional turbine.

4.3. Water turbines:

01. Pelton turbine, a type of impulse water turbine.

02. Francis turbine, a type of widely used water turbine.

03. Kaplan turbine, a variation of the Francis Turbine.

04. Voith, water turbine.

05. Wind turbine. These normally operate as a single without nozzle and interstage guide vanes. An exception is the Elaine Bole, which has a stator and a rotor, thus being a true turbine.

4.4. Steam Turbine:

Fig 4-2: A rotor of a modern steam turbine, used in a power plant

4.3.1. Steam turbine:

A steam turbine consists of an alternating series of one or more rotating discs mounted on a drive shaft, rotors, and static discs fixed to the turbine casing, stators. The rotors have a propeller-like arrangement of blades at the outer edge. Steam acts upon these blades, producing rotary motion. The stator consists of a similar, but fixed, series of blades that serve to redirect the steam flow onto the next rotor stage. A steam turbine often exhausts into a surface condenser that provides a vacuum. The stages of a steam turbine are typically arranged to extract the maximum potential work from a specific velocity and pressure of steam, giving rise to a series of variably sized high and low pressure stages. Turbines are only effective if they rotate at very high speed, therefore they are usually connected to reduction gearing to drive another mechanism, such as a ship's propeller, at a lower speed. This gearbox can be mechanical but today it is more common to use an alternator/generator set to produce electricity that later is used to drive an electric motor. A turbine rotor is also capable of providing power when rotating in one direction only. Therefore a reversing stage or gearbox is usually required where power is required in the opposite direction.

Steam turbines provide direct rotational force and therefore do not require a linkage mechanism to convert reciprocating to rotary motion. Thus, they produce smoother rotational forces on the output shaft. This contributes to a lower maintenance requirement and less wear on the machinery they power than a comparable reciprocating engine.

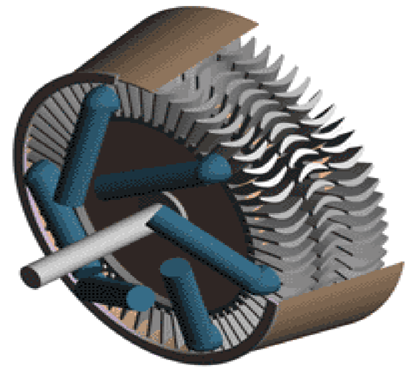

Fig 4-3: Steam turbine

4.5. Classification of steam turbine:

01. According to the mode of steam turbine

- Impulse turbine
- Reaction turbine

02. According to the direction of steam flow

- Radial flow inward
- Axial flow

03. according to the exhaust condition of steam

- Condensing turbine
- Non- Condensing turbine

04. according to the pressure of steam

- High pressure turbine
- Medium pressure turbine
- Low pressure turbine

05. according to the number of stages

- Single stage turbine
- Multi- stage turbine

4.6. Uses of turbines:

Almost all electrical power on Earth is produced with a turbine of some type. Very high efficiency turbines harness about 40% of the thermal energy, with the rest exhausted as waste heat.

Most jet engines rely on turbines to supply mechanical work from their working fluid and fuel as do all nuclear ships and power plants.

Turbines are often part of a larger machine. A gas turbine, for example, may refer to an internal combustion machine that contains a turbine, ducts, compressor, combustor, heat-exchanger, fan and (in the case of one designed to produce electricity) an alternator. However, it must be noted that the collective machine referred to as the turbine in these cases is designed to transfer energy from a fuel to the fluid passing through such an internal combustion device as a means of propulsion, and not to transfer energy from the fluid passing through the turbine to the turbine as is the case in turbines used for electricity provision etc.

Reciprocating piston engines such as aircraft engines can use a turbine powered by their exhaust to drive an intake-air compressor, a configuration known as a turbocharger (turbine supercharger) or, colloquially, a "turbo".

Turbines can have very high power density (i.e. the ratio of power to weight, or power to volume). This is because of their ability to operate at very high speeds. The Space Shuttle's main engines use turbo pumps (machines consisting of a pump driven by a turbine engine) to feed the propellants (liquid oxygen and liquid hydrogen) into the engine's combustion chamber. The liquid hydrogen turbo pump is slightly larger than an automobile engine (weighing approximately 700 lb) and produces nearly 70,000 hp (52.2 MW).

Turboexpanders are widely used as sources of refrigeration in industrial processes.

4.7. Operation of turbine:

A working fluid contains potential energy (pressure head) and kinetic energy (velocity head). The fluid may be compressible or incompressible. Several physical principles are employed by turbines to collect this energy:

4.7.1. Impulse turbines:

In the impulse turbine is prime mover in which rotary motion is obtained by the gradual change of movement of the steam. In a steam turbine, the force exerted on the blades is due to the velocity of steam. this is due to the fact that the curved blades the changing the direction of steam receive or impulse. the action of steam in this case is said to be dynamic .thus the dynamitycal pressur of steam rotes the vanes, bucket or blades directly .the turbine blades are curve in such a way that the steam directed upon them enter without shock, through there is always some loss of energy by the friction upon the surface of bleades.

Fig 4-4: runner and bucket of impulse turbine.

Its reference to the direction of flow of water, reaction turbine are divided into the following types-

4.7.2. Radial flow inward:

The runner reciver water under pressure in a radially inward direction and discharges it in a substantially axial direction .these are known as Francis turbine.

4.7.3. Axial flow:

The runner vanes of axial-flow turbine are either fixed or adjustable. These are propeller-type turbine and those with adjustable blades are known as Kaplan turbine.

These turbines change the direction of flow of a high velocity fluid jet. The resulting impulse spins the turbine and leaves the fluid flow with diminished kinetic energy. There is no pressure change of the fluid in the turbine rotor blades. Before reaching the turbine the fluid's pressure head is changed to velocity head by accelerating the fluid with a nozzle. Peloton wheels and de Laval turbines use this process exclusively. Impulse turbines do not require a pressure casement around the runner since the fluid jet is prepared by a nozzle prior to reaching turbine. Newton's second law describes the transfer of energy for impulse turbines.

4.7.4. Nozzle:

It is acicular guide mechanism, which guides the steam to flow at the designed direction and velocity . it also regulates the flow of steam .the nozzle is kept very close to the blades , in order to minimize the losses due to windbag.

4.8. Runner and blades:

The runner of a de-level impulse turbine essentially consists of a circular a disc fixed to a horizontal shaft . On the periphery of the runner number of bledes is fixed uniformly. The steam jet impingeson the buckets, which move in the direction of the jet. This movement of the blades makes the runner to rotate.

4.9. Reaction turbines:

In the reaction turbine the steam enter under pressure and flowover the blade. the steam ,while gliding, propels the blades and make them to move .as a mater of fact ,the turbine runner is rotated by the reactive forces of steam jet . The back ward motion of the blades is similar to the recoil of a gun.

Fig4-5: reaction turbine.

A person's turbine is simplest type of reaction steam turbine, and is commonly used. It has the following main componts.

4.9.1. Casting:

It is an air-tight metallic case, in which the steam from the boiler, under a high preassure and temperature, is distributed around the fixed blades in the casing. The casing is designed in such a way the steam enter the fixed blades with a uniform velocity.

Guide mechanism:

It is a mechanism made up with the help of guide blades, in the from of a wheel. This wheel is, generally, fixed to the casting; that is why these guide blades are also called fixed blades .the guide blades are properly designed in order to:

Allow the steam to enter the runner without shock. This is done by keeping the relatively velocity at inlet of the runner tangential to the blade angle.

Allow the required quantity of steam to enter the turbine. This is done by adjusting the opening of the blades.

The guide blade may be opened or closed by rotating the regulating shaft, thus allowing the steam to the need. These turbines develop torque by reacting to the fluid's pressure or weight. The pressure of the fluid changes as it passes through the turbine rotor blades. A pressure casement is needed to contain the working fluid as it acts on the turbine stage(s) or the turbine must be fully immersed in the fluid flow (wind turbines). The casing contains and directs the working fluid and, for water turbines, maintains the suction imparted by the draft tube. Francis turbines and most steam turbines use this concept. For compressible working fluids, multiple turbine stages may be used to harness the expanding gas efficiently. Newton's third law describes the transfer of energy for reaction turbines.

Turbine designs will use both these concepts to varying degrees whenever possible. Wind turbines use an airfoil to generate lift from the moving fluid and impart it to the rotor (this is a form of reaction). Wind turbines also gain some energy from the impulse of the wind, by deflecting it at an angle. Crossflow turbines are designed as an impulse machine, with a nozzle, but in low head applications maintain some efficiency through reaction, like a traditional water wheel. Turbines with multiple stages may utilize either reaction or impulse blading at high pressure. Steam Turbines were traditionally more impulse but continue to move towards reaction designs similar to those used in Gas Turbines. At low pressure the operating fluid medium expands in volume for small reductions in pressure. Under these conditions (termed Low Pressure Turbines) blading becomes strictly a reaction type design with the base of the blade solely impulse. The reason is due to the effect of the rotation speed for each blade. As the volume increases, the blade height increases, and the base of the blade spins at a slower speed relative to the tip. This change in speed forces a designer to change from impulse at the base, to a high reaction style tip.

Classical turbine design methods were developed in the mid 19th century. Vector analysis related the fluid flow with turbine shape and rotation. Graphical calculation methods were used at first. Formulae for the basic dimensions of

turbine parts are well documented and a highly efficient machine can be reliably designed for any fluid flow condition. Some of the calculations are empirical or 'rule of thumb' formulae and others are based on classical mechanics. As with most engineering calculations, simplifying assumptions were made.

Velocity triangles can be used to calculate the basic performance of a turbine stage. Gas exits the stationary turbine nozzle guide vanes at absolute velocity V_{a1}. The rotor rotates at velocity U. Relative to the rotor; the velocity of the gas as it impinges on the rotor entrance is V_{r1}. The gas is turned by the rotor and exits, relative to the rotor, at velocity V_{r2}. However, in absolute terms the rotor exit velocity is V_{a2}. The velocity triangles are constructed using these various velocity vectors. Velocity triangles can be constructed at any section through the blading (for example: hub, tip, midsection and so on) but are usually shown at the mean stage radius. Mean performance for the stage can be calculated from the velocity triangles, at this radius, using the Euler equation:

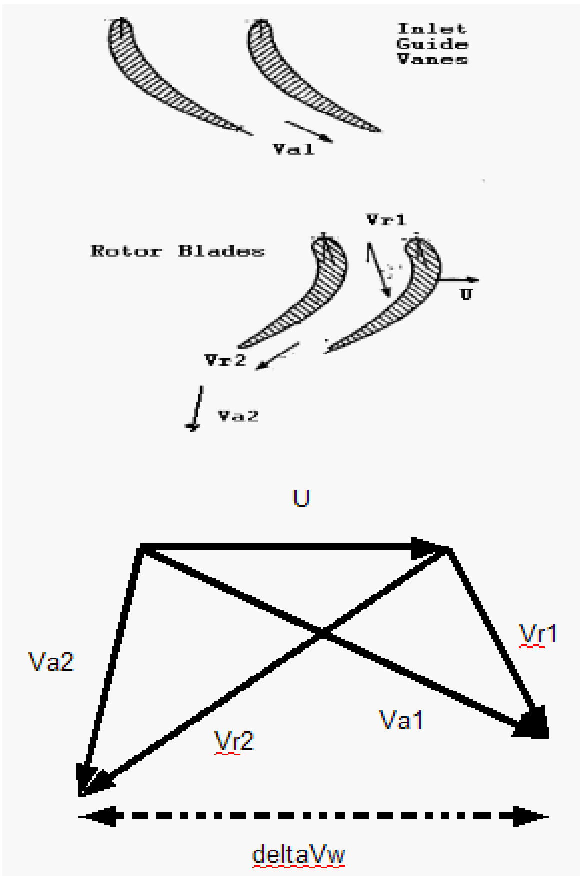

Fig 4-6: Typical velocity triangles for a single turbine stage

The turbine pressure ratio is a function of and the turbine efficiency.

Modern turbine design carries the calculations further. Computational fluid dynamics_dispenses with many of the simplifying assumptions used to derive classical formulas and computer software facilitates optimization. These tools have led to steady improvements in turbine design over the last forty years.

The primary numerical classification of a turbine is its specific speed. This number describes the speed of the turbine at its maximum efficiency with respect to the power and flow rate. The specific speed is derived to be independent of turbine size. Given the fluid flow conditions and the desired shaft output speed, the specific speed can be calculated and an appropriate turbine design selected.

The specific speed, along with some fundamental formulas can be used to reliably scale an existing design of known performance to a new size with corresponding performance.

4.10. Multi-level steam turbines:

In modern steam turbines not only one impeller is propelled, but several being in a series. Between them idlers are situated, which don't turn. The gas changes its direction passing an idler, in order to perform optimally work again in the next impeller. Turbines with several impellers are called multi-level. The principle was developed 1883 by Parsons. As you know, with the cooling gas expands. Therefore it is to be paid attention when building steam turbines to a further problem: With the number of passed impellers also the volume increases, which leads to a larger diameter of the impellers. Because of that, multi-level turbines are always conical.

4.10.1 Coupling of several turbines:

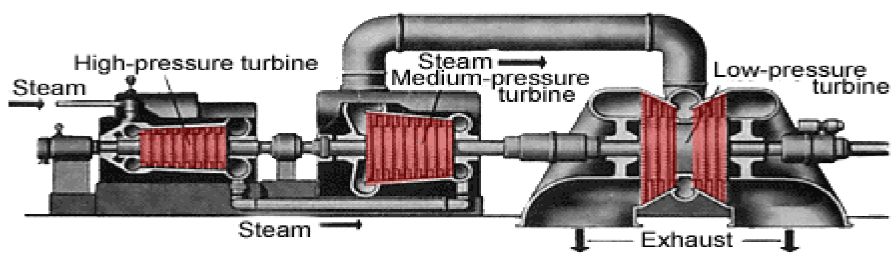

Fig 4-7: Graphic Coupled steam turbine. source: Helmut Hütten, "Motoren", Motorbuchverlag Stuttgart,

In power stations today, different types of turbines are used in a series, e.g. one high pressure -, two medium- and four low pressure turbines. This coupling leads to an excellent efficiency (over 40%), which is even better than the efficiency of large diesel engines. This characteristic and the relatively favorable production make the steam turbine competitionless in power stations. Coupled with a generator and fired by an atomic reactor, they produce enormously much electric current. The strongest steam turbines achieve today performances of more than 1000 megawatts.

4.10.2. Shrouded tidal turbines:

An emerging renewable energy technology is the shrouded tidal turbine enclosed in a venturi shaped shroud or duct producing a sub atmosphere of low pressure behind the turbine. It is often claimed that this allows the turbine to operate at higher efficiency (than the Betz limit[1] of 59.3%) because the turbine can typically produce 3 times more power [2] than a turbine of the same size in free stream. This, however, is something of a misconception because the area presented to the flow is that of the largest duct cross-section. If this area is used for the calculation, it will be seen that the turbine still cannot exceed the Betz limit. Further, due to frictional losses in the duct, it is unlikely that the turbine will be able to produce as much power as a free-stream turbine with the same radius as the duct.

Although situating the rotor in the throat of the duct allows the blades to be supported at their tips (thus reducing bending stress from hydrodynamic thrust) the financial impact of the large amount of steel in the duct must not be omitted from any energy cost calculations.

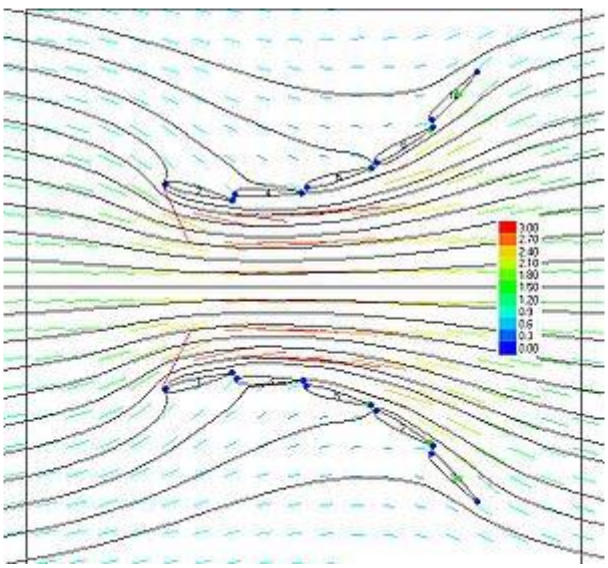

Fig 4-8: Asymmetric airfoil

As shown in the CFD generated figure, it can be seen that a down stream low pressure (shown by the gradient lines) draws upstream flow into the inlet of the shroud from well outside the inlet of the shroud. This flow is drawn into the shroud and concentrated (as seen by the red coloured zone). This augmentation of flow velocity corresponds to a 3-4 times increase in energy available to the turbine. Therefore a turbine located in the throat of the shroud is then able to achieve higher efficiency, and an output 3-4 times the energy the turbine would be capable of if it were in open or free stream. However, as mentioned above, it is not correct to conclude that this circumvents the Betz limit. The figure shows only the near-field flow, which is accelerated through the duct. A far-field image would show a more complete picture of how the free-stream flow is affected by the obstruction.

Considerable commercial interest has been shown in recent times in shrouded tidal turbines as it allows a smaller turbine to be used at sites where large turbines are restricted. Arrayed across a seaway or in fast flowing rivers shrouded tidal turbines are easily cabled to a terrestrial base and connected to a grid or remote community. Alternatively the property of the shroud that produces an accelerated flow velocity across the turbine allows tidal flows formerly too slow for commercial use to be utilised for commercial energy production.

While the shroud may not be practical in wind, as a tidal turbine it is gaining more popularity and commercial use. A non-symmetrical shrouded tidal turbine (the type discussed above) is mono directional and constantly needs to face upstream in order to operate. It can be floated under a pontoon on a swing mooring, fixed to the seabed on a mono pile and yawed like a wind sock to continually face upstream. A shroud can also be built into a tidal fence increasing the performance of the turbines. Several companies (for example, Lunar Energy [4]) are proposing bi-directional ducts that would not be required to turn to face the oncoming tide every six hours.

Cabled to the mainland they can be grid connected or can be scaled down to provide energy to remote communities where large civil infrastructures are not viable. Similarly to tidal stream open turbines they have little if any environmental or visual amenity impact.

4.11. Performance Monitoring:

The Steam Turbine Performance Monitoring application calculates, stores and displays

the main performance parameters that indicate condition and operating efficiency of steam

turbines. The calculations are based on steam turbine heat balance and built in accordance with

Appropriate DIN- and ASME-standards.

The storing of history values enables long-term reporting and trending of performance

parameters thus helping to detect gradual changes in steam turbine performance.

Introduction

Meeting the growing requirements for cost-effective and undisturbed operation in today’s

economical environment drives power plants to reach for the best possible performance

and higher availability. Power plants can no longer afford to operate without knowing the

exact steam turbine performance at all times and without taking immediate actions when problems occur. Steam turbine performance has a remarkable effect on power plant economy –

Efficiency drop of 2 % in 100 MW condensing steam turbine causes 300 000 EUR production loss,

unless the repair is optimally scheduled.

The Steam Turbine Performance Monitoring - a metsoDNA Plant Management application*

- provides the power plant maintenance and operating personnel with valuable information

about the performance, condition and operating efficiency of steam turbines both in real time

history.
The user interface of the application consists of customized display(s) and report(s) containing the

measured and/or calculated data. All calculations are based on existing instrumentation.

The Steam Turbine Performance Monitoring is a standardized application that can be used for

both back-pressure, district heating and condensing type steam turbines.

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4.11.1.Benefits:

The Steam Turbine Performance Monitoring provides the power plant maintenance and operating personnel with a tool that helps to detect potential problems in steam turbine Operation and analyze the problems that have occurred. This contributes towards proactively responding to failures before they cause unpredicted shutdowns.

The extensive storage of history data also enables long- term monitoring of gradual component deterioration, such as turbine-blade-deposit accumulation and thus improves scheduling of maintenance.

The Steam Turbine Performance Monitoring application is linked seamlessly to the overall automation applications, which guarantees efficient collaboration between plant management and plant control.

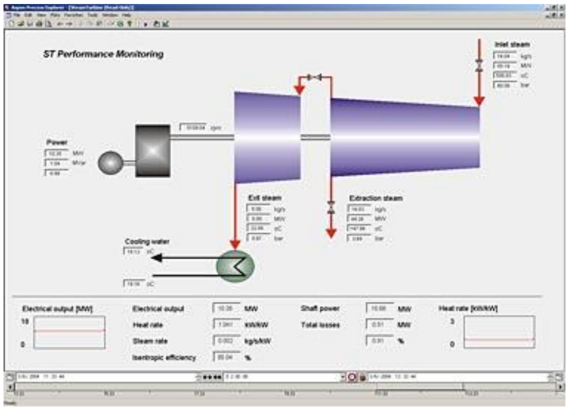

Fig 4-9: Features

The application includes calculation of the steam turbine heat balance, mass balance and the main performance parameters depending on the steam turbine type.

Back-pressure turbine: steam rate

District heating turbine: power to heat ratio

Condensing steam turbine: heat rate

The user interface of the application collects the performance data of the steam turbine

into easy-to-understand and -work-with report(s) and display(s).

The Steam Turbine Performance Display shows the current status of the steam turbine

heat and mass balance together with the steam turbine performance parameters in a visualized form.

The Steam Turbine Performance Report represents the long- term summary values of the

steam turbine heat balance, mass balance and performance parameters.

*

Fig 4-10: balance and performance parameters.

The metsoDNA Plant Management consists of modular applications specifically developed

for the energy industry to meet the monitoring, reporting and production optimisation needs

power plants.

The Plant management applications are designed to assist in all areas of power plant

operation - from management to production and maintenance

4.12. Others:

Velocity compound "Curtis". Curtis combined the de Laval and Parsons turbine by using a set of fixed nozzles on the first stage or stator and then a rank of fixed and rotating stators as in the Parsons, typically up to ten compared with up to a hundred stages, however the efficiency of the turbine was less than that of the Parsons but it operated at much lower speeds and at lower pressures which made it ideal for ships. Note that the use of a small section of a Curtis, typically one nozzle section and two rotors is termed a "Curtis Wheel"

Pressure Compound Multistage Impulse or Rameau. The Rameau employs simple Impulse rotors separated by a nozzle diaphragm. The diaphragm is essentially a partition wall in the turbine with a series of tunnels cut into it, funnel shaped with the broad end facing the previous stage and the narrow the next they are also angled to direct the steam jets onto the impulse rotor.

In this engine, air is sucked in from the right by the compressor. The compressor is basically a cone-shaped cylinder with small fan blades attached in rows (eight rows of blades are represented here). Assuming the light blue represents air at normal air pressure, then as the air is forced through the compression stage its pressure rises significantly. In some engines, the pressure of the air can rise by a factor of 30. The high-pressure air produced by the compressor is shown in dark blue.

4.12.1. There are many different kinds of turbines:

Most power plants use coal, natural gas, oil or a nuclear reactor to create steam. The steam runs through a huge and very carefully designed multi-stage turbine to spin an output shaft that drives the plant's generator.

Hydroelectric dams use water turbines in the same way to generate power. The turbines used in a hydroelectric plant look completely different from a steam turbine because water is so much denser (and slower moving) than steam, but it is the same principle.

Wind turbines, also known as wind mills, use the wind as their motive force. A wind turbine looks nothing like a steam turbine or a water turbine because wind is slow moving and very light, but again, the principle is the same.

A gas turbine is an extension of the same concept. In a gas turbine, a pressurized gas spins the turbine. In all modern gas turbine engines, the engine produces its own pressurized gas, and it does this by burning something like propane, natural gas, kerosene or jet fuel. The heat that comes from burning the fuel expands air,

something like propane, natural gas, kerosene or jet fuel. The heat that comes from burning the fuel expands air, and the high-speed rush of this hot air spins the turbine.

4.13. Advantage:

Following are the important advantage of steam turbines over reciprocating

Steam engines:

- A steam turbine may develop higher speed and a greater steam range is possible .
- The efficiency of steam turbine is higher.
- The steam consumption is less.
- Since all the moving parts are enclosed in the casing , the steam turbine is comparatively safe.
- A steam turbine requires less space and lighter foundation, as there are little vibrations.
- There is less frictional loss due to fewer sliding parts.

Chapter 5

Generator

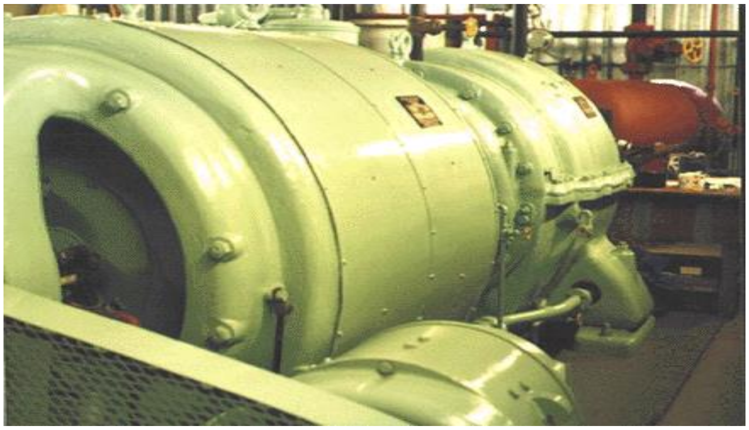

Fig 5-1: General Electric Steam Turbo generator

5.1. Definition:

1. device for producing electricity: a machine or device that is used to convert mechanical energy, such as that provided by the combustion of fuel or by wind or water, into electricity

2. device for producing gas: a device in which a gas is formed

3. Originator: somebody or something responsible for generating something such idea, plan, or strategy.

5.2. Steam generator

Steam generator, also called boilers; perform one of the major processes in a thermal energy cycle: vaporizing water to steam. Steam may generate mechanical power or supply heat to a manufacturing process. The complex equipment in a steam generator evolved from the simple cauldron of hero's engine of ancient history.

5.3. Types:

01.Westinghouse and Combustion Engineering designs have vertical U-tubes with inverted tubes for the primary water. Canadian, Japanese, French, and German PWR suppliers use the vertical configuration as well. Russian VVER reactor designs use horizontal steam generators, which have the tubes mounted horizontally. Babcock and Wilcox plants (e.g., Three Mile Island) have smaller steam generators that force water through the top of the OTSGs (once-through steam generators; counter-flow to the feed water) and out the bottom to be recirculated by the reactor coolant pumps. The horizontal design has proven to be less susceptible to degradation than the vertical U-tube design.

02. Wind powered generators: Wind turbines use the wind to generate and convert from kinetic to mechanical energy, funneling the usable energy to various pieces of equipment at one time.

Solar powered generator: If you're redoing your home or office, here's a great alternative. Obviously, solar power is energy generated by the sun's powerful emissions. Discreet photovoltaic shingles and panels harness and can even store this inexhaustible source of energy. All in all, solar power is one of the cleanest and least expensive ways to run a home or office.

03. Hand crank electric generator: The hand crank electric generator is the most primitive of the technological field, yet the most effective in extreme emergencies. In several emergency situations, a hand-cranked generator can be used to charge a cell phone, flashlight or radio in just a short time. These devices can then be used to alleviate the emergency, contact assistance, stay informed, and even save lives. Hand crank generators are commonly used as educational tools, to teach children the principles of electric currents and fields.

5.4. Operation of Steam generator:

Steam generators are heat exchangers used to convert water into steam from heat produced in a nuclear reactor core. They are used in pressurized water reactors between the primary and secondary coolant loops.

In commercial power plants steam generators can measure up to 70 feet in height and weigh as much as 800 tons. Each steam generator can contain anywhere from 3,000 to 16,000 tubes, each about three-quarters of an inch in diameter. The coolant (treated water), which is maintained at high pressure to prevent boiling, is pumped through the nuclear reactor core. Heat transfer takes place between the reactor core and the circulating water and the coolant is then pumped through the secondary tube side of the steam generator by coolant pumps before returning to the core. This is referred to as the primary loop. That water flowing through the steam generator boils water on the shell side to produce steam in the secondary loop that is delivered to the turbines to make electricity. The steam is subsequently condensed via cooled water from the tertiary loop and returned to the steam generator to be heated once again. The tertiary cooling water may be recirculated to cooling towers where it sheds waste heat before returning to condense more steam. Once through tertiary cooling may otherwise be provided by a river, lake, ocean. This primary, secondary, tertiary cooling scheme is the most common way to extract usable energy from a controlled nuclear reaction.

These loops also have an important safety role because they constitute one of the primary barriers between the radioactive and non-radioactive sides of the plant as the primary coolant becomes radioactive from its exposure to the core. For this reason, the integrity of the tubing is essential in minimizing the leakage of water between the two sides of the plant. There is the potential that if a tube bursts while a plant is operating; contaminated steam could escape directly to the secondary cooling loop. Thus during scheduled maintenance outages or shutdowns, some or all of the steam generator tubes are inspected by eddy-current testing.

In other types of reactors, such as the pressurised heavy water reactors of the CANDU design, the primary fluid is heavy water. Liquid metal cooled reactors such as the in Russian BN-600 reactor also use heat exchangers between primary metal coolant and at the secondary water coolant.

Boiling water reactors do not use steam generators, as steam is produced in the pressure vessel.

5.5. Typical operating conditions:

Steam generators in a "typical" PWR in the USA have the following operating conditions:

Side	Pressure, MPa (absolute)	Inlet Temperature, °C	Outlet Temperature, °C
Primary side (tube side)	15.5	315 (liquid water)	275 (liquid water)
Secondary side (shell side)	6.2	220 (liquid water)	275 (saturated steam)

5.6. Steam generator (Boiler):

A boiler or steam generator is a device used to create steam by applying heat energy to water. Although the definitions are somewhat flexible, it can be said that older steam generators were commonly termed boilers and worked at low to medium pressure (1-300 psi), but at pressures above that figure it is more usual to speak of a steam generator.

Fig 5-3: An industrial boiler, originally used for supplying steam to a stationary steam engine

A boiler or steam generator is employed wherever a source of steam is required. The form and size depends on the application: mobile steam engines such as steam locomotives, portable engines and steam-powered road vehicles typically use a smaller boiler that forms an integral part of the vehicle; stationary steam engines, industrial installations and power stations will usually have a larger separate steam generating facility connected to the point-of-use by piping. A notable exception is the steam-powered fireless locomotive, where separately-generated steam is transferred to a receiver (tank) on the locomotive.

5.7. Steam generator (component of prime mover):

The steam generator or boiler is an integral component of a steam engine when considered as a prime mover; however it needs be treated separately, as to some extent a variety of generator types can be combined with a variety of engine units. A boiler incorporates a firebox or furnace in order to burn the fuel and generate heat; the heat is initially transferred to water to make steam; this produces saturated steam at ebullition temperature (saturated steam which can vary according to the pressure above the boiling water. The higher the furnace temperature, the faster the steam production. The saturated steam thus produced can then either be used immediately to produce power via a turbine and alternator, or else may be further superheated to a higher temperature; this notably reduces suspended water content making a given volume of steam produce more work and creates a greater temperature gradient in order to counter tendency to condensation due to pressure and heat drop resulting from work plus contact with the cooler walls of the steam passages and cylinders and wire-drawing effect from strangulation at the regulator. Any remaining heat in the combustion gases can then either be evacuated or made to pass through an economiser, the role of which is to warm the feed water before it reaches the boiler.

5.8. Supercritical steam generator:

Supercritical steam generators are frequently used for the production of electric power. They operate at supercritical pressure. In contrast to a "subcritical boiler", a supercritical steam generator operates at such a high pressure (over 3200 PSI, 22 MPa, 220 bar) that actual boiling ceases to occur, the boiler has no liquid water - steam separation. There is no generation of steam bubbles within the water, because the pressure is above the critical pressure at which steam bubbles can form. It passes below the critical point as it does work in a high pressure turbine and enters the generator's condenser. This results in slightly less fuel use and therefore less greenhouse gas production. The term "boiler" should not be used for a supercritical pressure steam generator, as no "boiling" actually occurs in this device.

Chapter 6

Overall Controls

6.1. Controls:

Instruments are installed in a power station for a number of reasons. The main function of the instruments is as follows

6.1.1. Operation guidance:
The instruments are a guide to safe, continuous and proper plant operation.

6.1.2. Economic supervision:

Performance evaluation: The instruments furnish data for evaluating overall plant performance and checking the efficiency of individual plant component.

Costs and costs allocation: the cost accounting system depends on meter readings and corrects cost figures may point to wards possible economies.

Maintenance guidance: Instruments check on the internal condition of equipment and indicate when and where maintenance or repair is needed.

This system uses adoption of electrical transmitter /transducer with signal rang of 4-20mA dc and to wire system is obtained flexibility and standard dilation of signal range with computerized data actuation system.

6.1.3. Control Requirement:
Controlles must meet several criteria:

1. Sensitivity.

2. Speed.

3. Stability.

4. Power

5. Ruggedness

maintaining reasonably constant steam presser requires enough sensitivity to detect small steam pressures change . This allows initiating corrective movement of fuel and air controls soon enough. booth air and fuel flows need time to speed up or slow down to meet the new demand level for steam .

The total time lag of a control system has three parts :

1. Time for the master regulator or controler to respond to respond to steam pressure change.

2. Time for the fuel feeder and fan speed or damper to reach the new value or setting .

3. Time for the steam pressure change to respond to the new input rete.

6.2. The main purpose of providing controls is as follows:

01. Safety: Controls to prevent damage.

02. Convenience of operation.

03. Overall operation efficiency.

04. Reduction of operating cost.

6.3. Selection of instrumentation:

Several factors should be considered in deciding the proper type of instrumentation and controls for a steam station. Some of the factors are as follows:

Boiler and Cycle design: Size, complexity, and operating conditions.

Type of fuel used: Coal, gas, oil and fuel burning equipment.

Feed water system: Drum size, pump characteristics.

Auxiliary equipment: Such as fan arrangements, source of fan power, damper arrangements, etc.

Load characteristics: Anticipated change, rate and magnitude of change.

6.4. Automatic Control Systems:

The steam station being a combination of complex processes requires a combination of several closely allied control systems.

The types of the control systems used are:

- On-Off or 2 position control.
- 3 position or multiposition control.
- Fixed speed floating control.
- Variable speed floating control- integral action.
- Proportional control.
- Derivative control.

6.5. COMBUSTION CONTROL SYSTEM:

In selecting a combustion control system, some of the following factors should be taken into consideration:

- Type of Boiler.
- Its capacity, maximum operating pressure and temperature.
- Range of minimum to maximum load.
- Pattern of load.
- Type of fuels, their availability and the sequence in which they should be burned.
- Types of burner.
- Arrangement of fans and dampers.

6.6. The main function of a combustion control system:

To supply the correct amount of fuel and air to the furnace so as to release heat as required by the heat demand.

To minimize controllable losses due to excess air or incomplete combustion by adjusting suitable fuel/air ratio.

6.7. STEAM TEMPERATURE CONTROL SYSTEM:

With the increase in system temperature and adoption of the reheat cycle in modern boilers, accurate control of steam temperature is very important to insure best operation of the system. Many operating variables such as load, excess air, feed-water temperature, heating surface cleanliness, and burner operation affect steam temperature.

The methods used for steam temperature control are as follows:

- Desuperheating
- Gas by-passing
- Gas recirculation
- Excess air
- Burner tilt

6.8. FEED WATER CONTROL SYSTEM:

A feed water control system has to perform three functions:

Control the level of water in the boiler drum and prevent damage from burning out boiler tubes because of low water in the boiler drum. Prevent an abnormally high water level in the boiler drum to avoid the change carrying over dissolved solids with the steam into the super heater.

Regulate the water in such a manner that the entire system is kept approximately in balance and not subjected to severe changes in the water flow.

6.9. The types of the water control systems:

01. Single element self operated.

02. Single element relay operated.

03. Two element relay operated.

04. Three element relay operated.

6.10. CENTRALISED CONTROL:

A central control room is located between boiler and turbine rooms. Most of the controls are automatic, and centralized control with a number of annunciations and indicating instruments helps in controlling the operation of the steam station effectively. The recent trend is towards the common control. Centre for boiler, turbine generator and auxiliary equipment. This has resulted in marked reduction in operating staff and improved supervision through co-ordination of the various segments of plant operation, Application of miniature equipment has made the operating panel compact. The miniature instruments are pneumatic and electronic receivers, coupled with pneumatic and electric recorders which permit transmission of values from the location of the primary elements, The latest trend in highly automated steam power station is the use of computers to perform functions such as data logging, alarming, scanning and performing monitoring. In this way the steam station can be considered as the whole plant. The fuel supply, feed water and air supply is directly integrated with load changes.

6.11. Control Panel:

The control panel for the above generator was built in 1960 and again it was rebuilt by Dynamic Energy Corp. for this installation. The power plant has an independent control panels separate from incinerator control panels. There are two control panels. One is totally devoted to alternator monitoring and protection. The other panel is used to control entire power house equipment and switch gear.

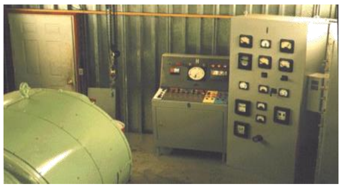

Fig6-1: Power Plant Control Panels

6.12. Switch gear: We used old Allis Chalmers 1,600 Amps breakers to connect or interrupt the electric power from alternator. These are motor operated breakers for closing. Breaker tripping mechanism is actuated by DC electromagnet which is powered with DC current from large electrolytic capacitor. This ensures that there is always enough power to trip the breaker when all other power fails, as in the case of short circuit. Electronic protection relays are used to activate the breaker trip mechanism when fault conditions get out of specified limit. Two breakers are used. One breaker feeds electric panels for power distribution in the incinerator plant the second breaker can connect electric power to utility Grid.

6.13. Electric-type Control: Through the mixer amplifier anticipatory signals are sent to the governor nor motor in parallel with those sent to the fuel feed controler. these impulse make the boiler fuel input change simultaneously with change in governor motor position even before the generator change are fully made .as generator output responds to the new load demand ,the fuel input keeps in step. to maintain a proper fuel – air ratio with changing load, the O2 recorder sends adjusting the control system for the best combustion gas condition with changing fuels .this system has four element :

1. Load (generator output) - proportional action.
2. Steam pressure – final adjustment, or trim.
3. Governors' motor impulse –anticipatory action.
4. Automatic correction.

6.14. Automatic tripping:

The turbine generator is cross component, each fed by a single steam generator.

Thrust-bearing failure: thermocouples inserted in the matel backing of the babbitted trust shoes give fast response to changes in Mata temperature. the thermocouples actuate an alarm at 10F above normal ; at 190F they operate the auxiliary relay to trip out fuel supply and the turbine stop valve.

Excess ire vibration: vibration velocity pickups on the turbine –bearing pedestals actuate in auxiliary relays to trip turbine and boiler if the turbine rotors should become unbalanced from heavy rubs or throngs a blade. vibration pickups on the outboard bearing pedestals of the generator protects it from mechanical unbalanced , such as failure of the cooling fan, and also electrical unbalanced caused by double winding grounds in the rotor.

Loss of vacuum: rupture diaphragms in the exhaust shell prevent positive pressure in the condenser on the loss of circulating water to trip the machine in advanced of disk rupture, a vacuum –measuring device is used. This sound an alarm at 27in. hg vacuum and trips out the boiler and turbine at 20 in hg vacuum.

Shaft over speed: a conventional over speed governor on the turbine shaft trips the main turbine stop valve , governor valves , and reheat intercept valves.

Quick stating: these reheat unit have quick –stating bypass valves around the main and reheat cylinders to the condenser to established mass steam flow through superheated repeater so that both main and reheat steam temperature about 100F above the chest-metal temperature of the respective cylinders before opening the turbine control valves.

Generator and transformer deferential: these electrical troubles are beyond the scop of this book .

Generator ground: a relay in the main circuit trips both turbine and boiler out of circuit when generator insulation fails.

Loss of generator fails: a relay in the field circuit trip the unit on any reduction of field current which would cause reactive flow into the generator and upset steam stability . this relay function also when out-of-step operation seems imminent .

Generator monitoring: a reverse-power relay in the high –pressure generator circuit trip out the unit when steam flow is not enough to supply no load loss .monitoring of the unit is likely to damage the low pressure blades by overheating from winding.