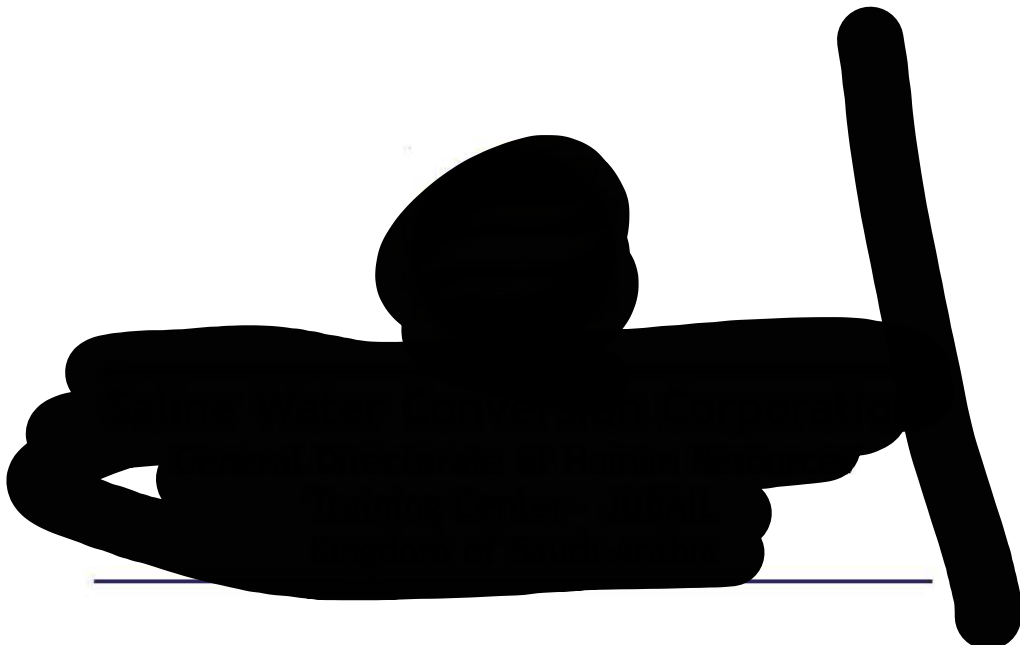


# Introduction to Power Plants





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# 1

## Introduction to Power Plants



### STRUCTURE

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  - 1.2.2 Back-Pressure Turbine
- 1.3 Generating Steam**
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## 1.0 INTRODUCTION

In a dual purpose thermal power plant, fuels (like oil, gas and coal) are burnt in order to generate electric power and produce potable water. Therefore, thermal power plants act as energy converters. They have different cycles, each of which makes use of a medium for its completion. Apart from thermal power plants, there are other types of power plants like hydroelectric, nuclear and non-conventional power plants. The hydroelectric power plant, in particular, is very important since it does not cause any kind of pollution as the energy of water is converted into electricity. Similarly, in nuclear power plants, the energy released due to nuclear fission is converted into electricity. In the case of non-conventional power plants, solar, wind and tidal energies are converted into electricity.

In this lesson, you will learn the basic principles of power plants.

## 1.1 LEARNING OBJECTIVES

After going through this lesson, the trainee should be able to:

- ▶ Understand the working of steam power plants
- ▶ Know the process of generation of steam
- ▶ Learn about steam and condensate process steam
- ▶ Calculate the efficiency of thermal units
- ▶ Comprehend the process of working of hydroelectric power plants
- ▶ Know the contribution of different sources in the generation of electricity

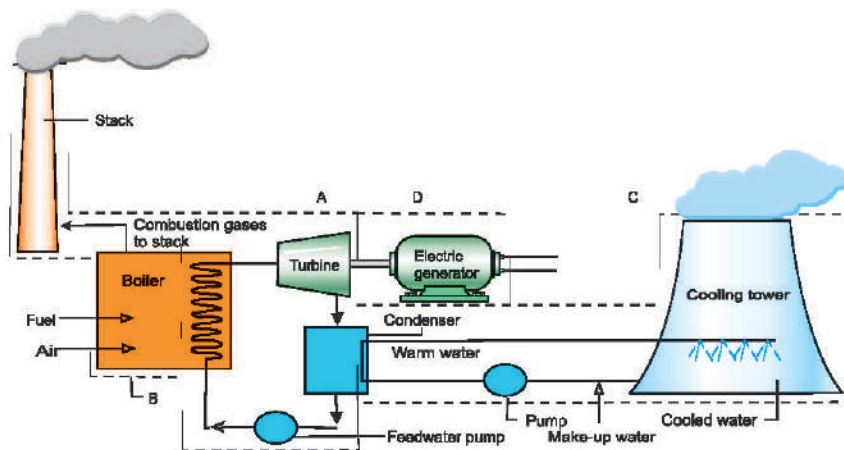
## 1.2 STEAM POWER PLANT

In a steam power plant, water and steam play the role of an energy carrier and are also known as the working medium. The working of this plant involves the effective use of natural resources, in order to generate power that is clean and environment friendly. Figure 1.1 shows the steam power plant.



▲ Figure 1.1 Steam Power Plant

Development in steam power plants involves the maximum utilization of resources and energy while considering all standard environmental norms. As you already know, this medium performs a cycle that goes on to generate energy. Figure 1.2 shows a condensing turbine that uses water and steam in its cycle.



▲ Figure 1.2 Condensing Turbine

Based on Figure 1.2, the following conclusions can be drawn:

- ▶ Feedwater is supplied to a boiler after being compressed by boiler feedwater pumps (BFP).
- ▶ The water is heated in the boiler heating area and is converted to steam.
- ▶ The steam is led to the prime mover (steam turbine) which then expands.
- ▶ The expanded steam (after giving power to the turbine) is led into a condenser and is cooled by cooling water.

After condensing exhaust steam in the condenser, the water is led to the BFP to repeat the cycle again through the boiler. Therefore, the steam power station acts as an energy converter which makes use of this water cycle. In order to perform such a cycle, various equipment are also set up in a thermal power plant.

Steam, which is rapidly conveyed through pipelines to the turbine, is generated in a boiler by the burning fuel in a furnace.

There are two types of turbines that are used in steam power plants—**condensing** and **back-pressure** turbines. They act as the prime movers which transform a thermal energy to mechanical energy.

### 1.2.1 Condensing Turbine

The prime mover of steam power plants is operated at the condensing stage (as shown in Figure 1.2). Exhaust steam from prime movers is led into a condenser whose pressure is less than atmospheric (vacuum) pressure. It is here that the steam is changed to water.

The prime mover does not get to utilize the total energy carried by the steam since much of the heat is lost during the condensing operation (steam gets converted to water). The main advantage of the condensing operation is that it increases the amount of electrical energy generated per kilogram of steam.

In the condensing operation, exhausted steam from the prime mover is changed to liquid (water) in a condenser. There is a remarkable drop of pressure with the rapid condensation of steam exhausted from the prime mover. Since the specific volume of steam is higher than water, the condensation of steam results in a drop in pressure in the condenser. A further drop in the exhaust steam pressure is secured by a device (either a vacuum pump or an air ejector). This is done to remove air and other non-condensable gases which exert

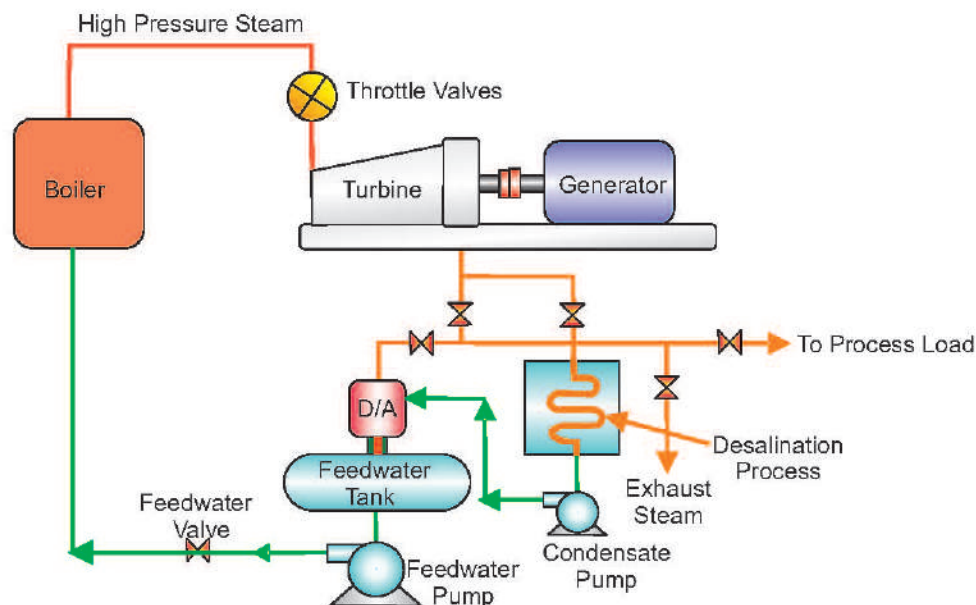
pressure within the condenser. As a result air leaks into the condenser and is carried in by the exhaust steam along with foreign gases.

Under permissible conditions, exhaust steam discharged by the turbine enters into the condenser under vacuum of 660 mm of mercury, which is read as 760 mm of mercury in the barometer.

### 1.2.2 Back-Pressure Turbine

The steam exhausted from the turbine may have some amount of remaining energy. In order to utilize the energy left in the steam, condensation is not done at this stage and the steam is reused in the process of work. This is true in case of a back-pressure turbine. Here, the exhaust steam is led to the equipment to make use of the energy instead of leading it directly to the condenser.

In case of a desalination plant combined with a power plant, exhaust steam from the turbine is led to the desalination units. Here, the exhaust steam functions as the heating medium while it is simultaneously being cooled. It then condenses into water and is led to the deaerator, which removes extra air from the water. The process of condensing increases the amount of energy used per kilogram (kg) of steam. Therefore, the cooling process is complete and the medium returns back to the compression process in cycle (that is, the de-aerator). Figure 1.3 shows the back-pressure turbine system.

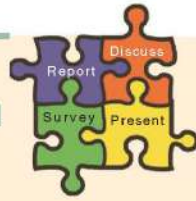


▲ Figure 1.3 Back-Pressure Turbine

**Stop**

#### Check Your Progress

1. What constitutes the working medium in a steam power plant?
2. Name the two types of turbines in a steam power plant.
3. What is the advantage of the condensing operation?



1. Trace the water and steam line in a diagram of power plant drawn by you on the class board. (P)
2. Compare condensing and back-pressure turbines. (M)

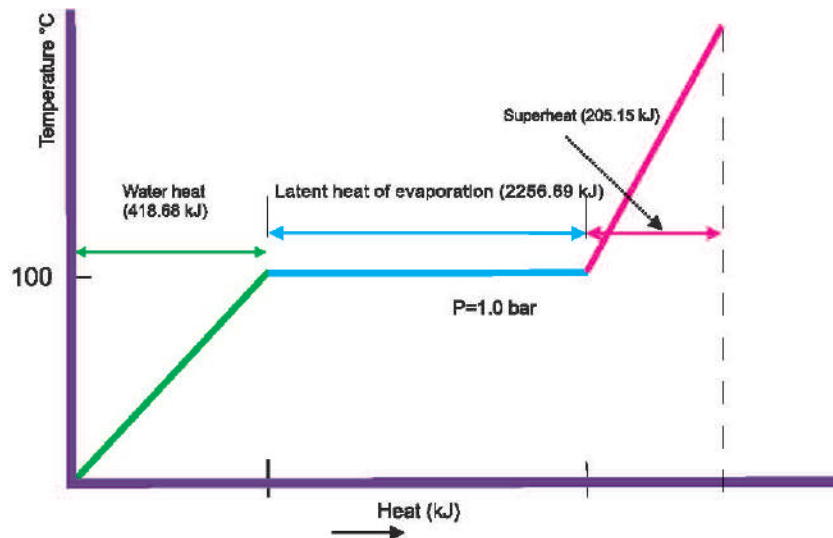
### 1.3 GENERATING STEAM

You are aware that to turn water into steam, it is necessary to add heat to it. Water reacts to the heat in a certain manner, depending on how far it is placed in the process of boiling. On the basis of this, there are three different forms of steam—**dry**, **wet** and **superheated**. Wet steam is a kind of steam that consists of vapour as well as liquid. This liquid is the water that has not been totally converted into vapour. Dry steam consists of vapour only and there is no liquid. On the other hand, superheated steam is a kind of steam that is heated above its saturation temperature.

In order to understand this concept further, consider that there is 1 kg of water at 0°C in a flask. When heat is added to the water, its temperature will increase. It continues to increase until the water begins to boil and the temperature stops rising. If the flask is open to the atmosphere, the temperature stops at 100°C and hold steady at that value. If we turn the heat off in order to stop the boiling, the remaining water will also have temperature of 100°C.

The temperature at which water starts boiling and is turned into steam is the saturation temperature. At atmospheric pressure, the saturation temperature is 100°C. This fact cannot be altered as long as the pressure remains at the atmospheric condition. You must also know that water that is not boiling but is at the saturation temperature is called saturated water. This means that the water has been charged with heat to the point where it can absorb no more without beginning to boil. Water at atmospheric pressure with a temperature below 100°C (the saturation temperature) is called sub-cooled water. Most of the water in your plant is sub-cooled, as you will learn later.

The concepts just explained can be displayed on a graph (as seen in Figure 1.4) that has its temperature along the vertical axis and heat along the horizontal axis. As heat is added to sub-cooled water, its temperature increases from 0°C to 100°C. On adding more heat, the water begins to boil but the temperature remains at 100°C.



▲ Figure 1.4 Heat Content Vs Temperature Graph

If you continue to add heat to the boiling water, all the water will turn into steam. If you measure the temperature of the steam at the exact instant when the last drop of water has turned into steam, you will see that it is still 100°C. At this point, you have saturated and dry steam. It is saturated because its temperature is at the saturation temperature of 100°C and it is dry because no liquid water is left.

At any point in between, when the entire amount of water is not converted into steam, a mixture of steam and water will exist. The ratio of the amount of pure dry steam to the total amount of the mixture (containing steam and water particles) is called the dryness fraction.

Furthermore, if this dry steam is heated more, its temperature will go up. The same thing happens when sub-cooled water is heated. In its liquid or vapour form, the temperature of the fluid will increase when heat is added. However, when the liquid and vapour are in a mixture, the addition of heat does not cause a change in temperature. Rather, it causes more liquid to be turned into vapour. Our graph can now be completed and all the regions can be identified.

As you must have noticed, values have been placed on the temperature axis but there are none on the heat axis till this point. There is a property of steam and water that can be used to determine the amount of heat necessary to increase the temperature of 1 kg of either fluid. This property is called specific heat. Specific heat is the heat (in kJ) that is necessary to raise the temperature of 1 kg of a substance by 1°C/°K.

Using this definition, you can see that the specific heat of water is:

$$4.2 \frac{\text{kJ}}{\text{kg}^\circ\text{K}}$$

$$\text{Heat of steam as } 2.1 \frac{\text{kJ}}{\text{kg}^\circ\text{K}}$$

In order to determine the specific heat of steam, you will have to notice how steep the graph is for superheated steam as compared to sub-cooled water, where it is twice as steep. In other words, it takes less heat to increase the temperature of the steam by 1°C. You can use the property of specific heat and the following relationship to calculate heat values for use on the heat axis of our graph:

$$\text{Heat} = \text{Weight} \times \text{Temperature change} \times \text{Specific heat}$$

(kJ)      (kg)      (°K)      (kJ/kg °K)

When phase change takes place, the formula to be used is,

$$\text{Heat} = \text{Mass} \times \text{Latent heat}$$

The types of heat mentioned are **water heat** and **superheat**. Water heat is the amount of heat required to raise the temperature of 1 kg of water from 0°C to 100°C. Superheat is the amount of heat required to raise the temperature of 1 kg of steam from 100°C to a final temperature.

### 1.3.1 Latent Heat of Evaporation

The amount of heat required to turn saturated water into saturated steam cannot be calculated by using specific heat values of the water and steam. The reason for this is that specific heat is temperature dependent and as you already know, the unit of specific heat is kJ / °C. However, in the process of converting saturated water into saturated steam, the temperature remains constant.

Heat energy that is absorbed is further used to change the state of the fluid from liquid to vapour. Since the temperature does not change, there is no obvious way to determine how much heat is being used. This quantity of heat is called the latent heat of evaporation. The term 'latent' means present but not visible while 'evaporation' refers to the process of changing the state from liquid to vapour. The heat is absorbed during boiling and is given out when the steam is turned back into water (condensation).

Laboratory experiments have shown that the heat energy involved in the latent heat of evaporation is 2256.69 kJ/kg at atmospheric pressure. Here, the units do not include °C, since the process of boiling does not cause a change in the temperature. The heat of water is 418.68 kJ for 1 kg of water and the superheat is 200.97 kJ. With this information, the heat graph can be completed as shown in Figure 1.4.

The total heat content of 1 kg of superheated steam is equal to the sum of the water heat plus the latent heat and the superheat. This adds up to 2880.52 kJ for one that kilogram of steam. Notice that the latent heat forms the largest part of the total heat. From the graph, you can also see that the advantage of using steam in a power plant is its ability to absorb, transport and release large amounts of heat energy.

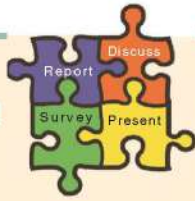
At this point, you also need to know about the following concepts:

- ▶ **Sensible heat:** It is the amount of heat required to raise the temperature of 1 kg of steam or water by 1°C.
- ▶ **Latent heat of condensation:** It is the amount of heat removed from 1 kg of steam to form 1 kg of water at the same temperature.

**Stop**

#### Check Your Progress

4. Name the three different types of steam.
5. Define saturation temperature.
6. What is sub-cooled water?
7. What is superheated steam?
8. What is water heat and superheat?
9. Define sensible heat.

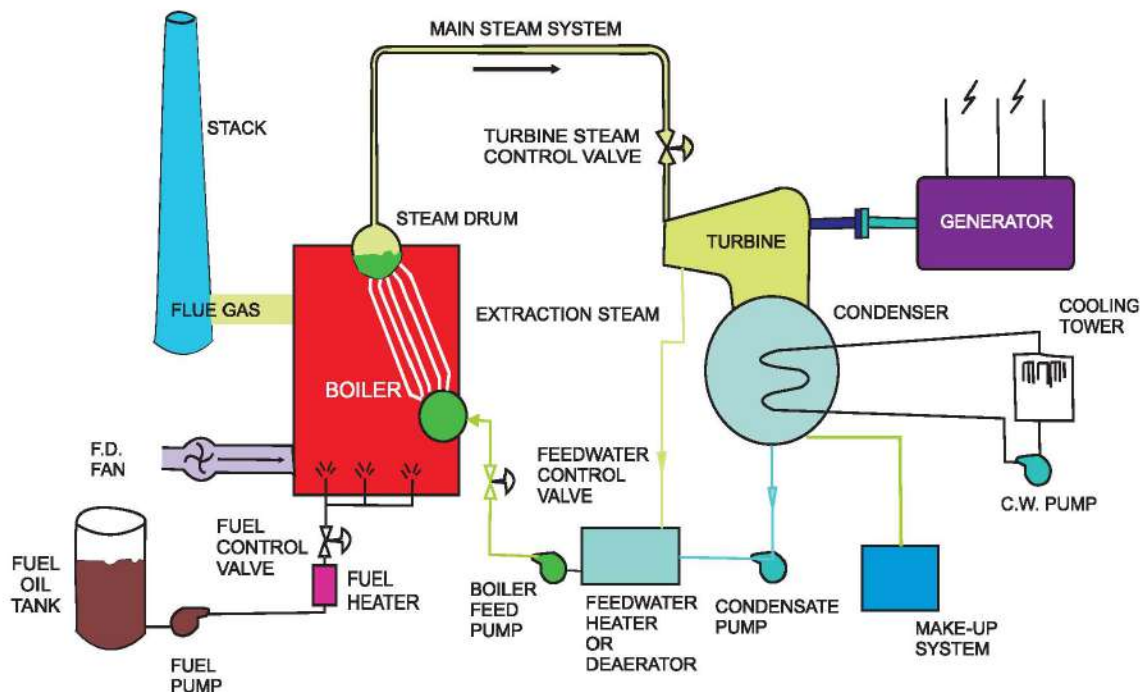


1. Draw a heat content vs temperature diagram showing the different phases of water. (P)
2. Prepare a PowerPoint presentation showing the state of water (or steam) at different stages of the working of a power plant. (M)

## 1.4 STEAM AND CONDENSATE PROCESS SYSTEM

The boiler produces steam in the power plant and the control valves regulate the steam flow to the turbine. The steam then expands and performs mechanical work in the turbine. From the turbine, extraction steam goes to the feedwater heater and exhaust steam goes to the condenser. In the condenser, the exhaust steam is cooled by circulating water causing it to condense to pure water and this is known as condensate.

The condensate pump takes the condensate from the condenser and feeds it through a heater to the boiler feed pump. This supplies water to the boiler through another feedwater heater. The extraction steam heats the feedwater before it reaches the boiler. A feedwater control valve controls feedwater flow to the boiler and this completes the cycle. A make-up water system compensates for any loss of water or steam from the cycle. Figure 1.5 shows the flow diagram of a power plant.



▲ Figure 1.5 Flow Diagram of a Thermal Power Plant

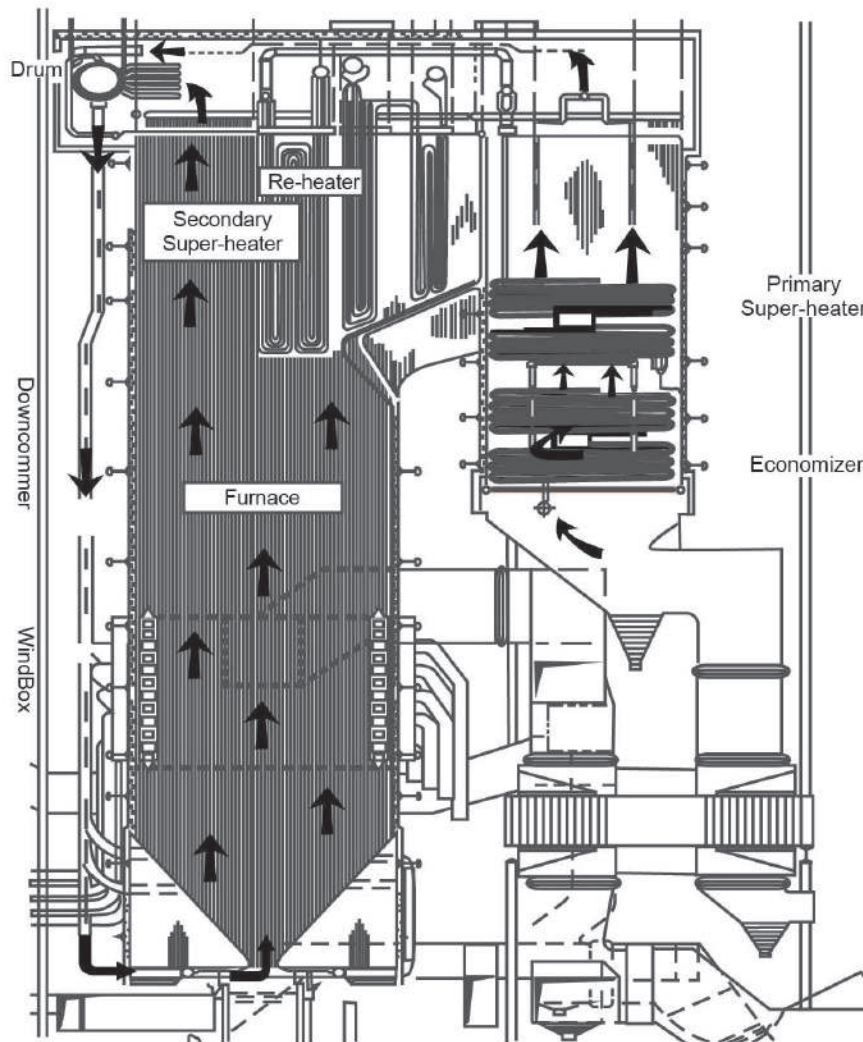
### 1.4.1 Water and Steam Flows in the Boiler

Water is fed into the steam drum which is located on top of the boiler. From the bottom of the drum, water flows downwards to the bottom of the boiler through unheated tubes or pipes which are called down-commer.

At the bottom of the boiler, the water is collected in large distribution pipes called headers. Welded into the headers are a large number of smaller pipes which pass up through the furnace back to the steam drum. These pipes can be called water wall tubes, risers, furnace wall tubes or boiler tubes.

The furnace chamber is a cage made of metal walls of water tubes or risers. Combustion heat is transferred through the metal tube to the water. This heat causes the water to become a mixture of steam and water which rises into the drum.

In the drum, steam separates from the water-steam mixture and the steam bubbles are cleaned and dried by the equipment which is installed for that purpose. This is done so that the steam leaves the top of the drum with no moisture. At this point, the steam is a hot and dry gas. Water collects in the lower part of the drum to begin the natural circulation process. As steam is released, the water level in the drum decreases.



▲ Figure 1.6 Flow Paths for Production of Steam

To maintain the level, water is added to the drum which is called feedwater. Dry steam is sent from the boiler drum to the superheaters (through pipes), where its temperature is increased to improve efficiency. The temperature of the steam leaving the drum varies from approximately 307°C (for a boiler operating pressure of 96.53 bar g) to 354°C (for a boiler operating pressure of 172.37 bar g). In a modern boiler, the final temperature of the superheated steam leaving the boiler is usually 537°C.

This process of superheating increases the energy of the steam and allows it to be used more efficiently in the turbine. Figure 1.6 shows this process.

### 1.4.2 Main Steam System

The steam leaving the boiler through a large number of individual tubes is piped to large manifolds or headers which tie into one or more large diameter pipes. These then run into the turbine. The main steam system also supplies steam to the turbine gland seal system and the air ejector. There are usually either two or four main steam pipes in parallel lines.



#### Check Your Progress

10. What is the use of control valves in the boiler?
11. What is the use of a make-up water system?

### Classroom



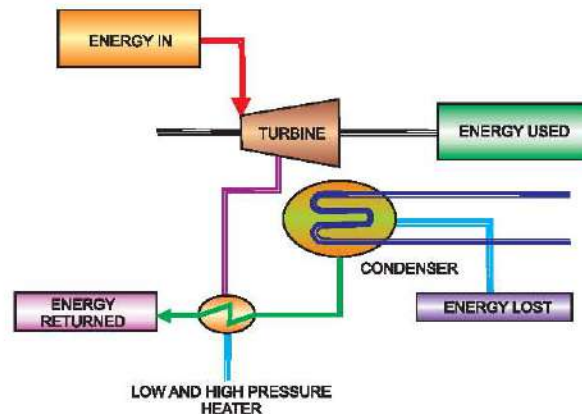
### Activities

1. On the class board, draw and label the flow path for the production of steam. (P)
2. Draw a picture of a boiler (with all the heating elements like evaporator and superheater) and present it to your class. (P)
3. Boil some water and record the different stages it passes through before converting to vapour. Analyse the wet phase. (M)

## 1.5 EFFICIENCY OF THERMAL UNITS

In a power plant, there are thermal and mechanical losses (which reduce the amount of available energy) at each stage of its operation, which is shown in Figure 1.7.

The overall efficiency (ratio of useful energy output to the energy contained in the fuel supplied) ranges from 23–38 per cent for condensing plants. The highest efficiencies can be obtained only in those plants that have the essential equipment to optimize the energy supplied. Other factors that help in high-efficiency operation are natural advantages (like the availability of cooling water in ample quantities), proper maintenance and careful operation.



▲ Figure 1.7 Steam-Water Cycle Energy Diagram

The efficiency of a boiler is commonly expressed in percentage and is indicated by the percentage of energy supplied to the boiler compared to what is contained in the final product leaving the boiler.

The procedure to determine the efficiency of power plants is as follows:

- Based on input and output quantities, it can be calculated by the following method:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

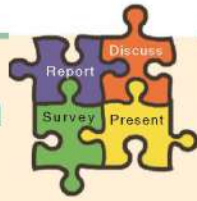
- Based on measurable or estimated losses in the system, it may be calculated as follows:

$$\text{Efficiency} = \frac{\text{Input} - \text{Losses}}{\text{Input}} = \frac{\text{Output}}{\text{Output} + \text{losses}}$$

**Stop**

### Check Your Progress

12. What is the overall range of efficiency for a condensing plant?
13. State the formula to calculate the efficiency based on input and output quantities.



1. Make a list of the various instances of losses of energy in your power plant. (P)
2. Prepare a report on the efficiency of your power plant based on various aspects. Also, suggest methods to reduce losses of energy that occur in your plant. (M)

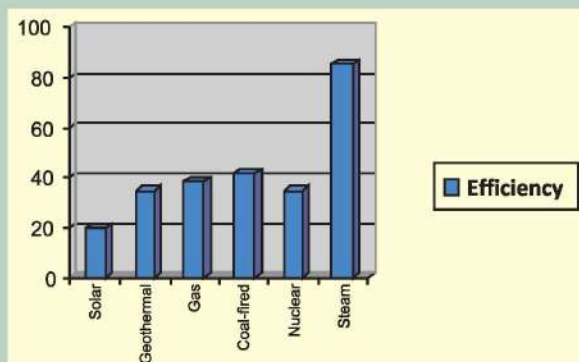


## Case Study - I

### Survey on Efficiency of Power Plants

#### Scenario

MBA graduates of a college were given an assignment to prepare a project report on the efficiencies of different power plants. They surveyed various power plants throughout the country and tried to determine their exact efficiency. On the basis of their inference, they prepared the following bar diagram:



They found out that among all these plants, the efficiency of the steam power plant was the highest. The high degree of efficiency of these plants was source of water available right next to the turbine. Therefore, there were no losses in energy conversion. There were only mechanical and copper losses in the turbine and generator. So, it was the most efficient plant.

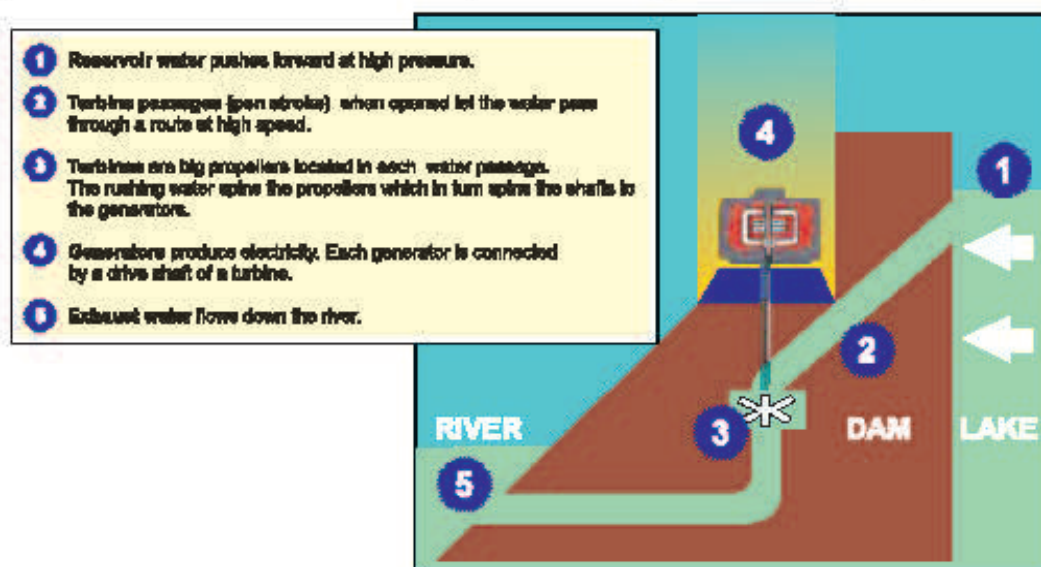
1. Which power plant had the maximum efficiency, according to the survey? (P)
2. Prepare a presentation on why the steam power plant had the maximum amount of efficiency. (M)

## 1.6 HYDROELECTRIC POWER PLANT

In a hydroelectric power plant, water is the driver of the turbine. In it, water flows from an elevated tank through a pipe and strikes the turbine blades, which causes the turbine to rotate. Therefore, the potential energy of water is converted into the mechanical energy of the rotating turbine. The mechanical energy of the water wheel can be varied by regulating the amount of water flowing through the turbine.

In a hydroelectric power plant, the water level is raised by a dam and the turbine is mounted either vertically or horizontally at the foot of the dam. The turbine can be of various types depending upon the height of the water available at the location.

Figure 1.8 illustrates the various components of a hydroelectric power plant.



▲ Figure 1.8 Hydroelectric Power Plant

### 1.6.1 Some Other Power Plants

Besides the conventional power plants discussed, there are some other types of power plants which are relatively new. The most important of these are nuclear power plants, in which the energy released due to nuclear fission is used to generate the steam and thus, conventional fuels (like coal) are replaced with nuclear fuel. However, due to the use of nuclear fuel, utmost care is needed to avoid exposure of these plants to radiation.

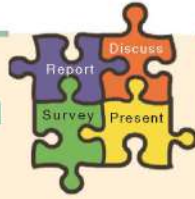
Besides this, there are certain non-conventional sources of energy in which electricity is generated by tidal, geothermal, ocean, wind, solar, photovoltaic and thermionic sources.

Stop

#### Check Your Progress

14. Name the element that drives the turbine of a hydroelectric power plant.
15. How can the mechanical energy of the water wheel be varied?

## Classroom



## Activities

1. Visit a hydroelectric power plant and make notes on the major components that are essential for its operation. (P)
2. Make a list of the non-conventional sources of energy and prepare a class presentation on how any one of these sources of energy is converted into electricity. (P)
3. Prepare a video documentary of the various non-conventional sources of energy used across the world. Present the same in your class and describe the importance of each source. (M)



### Case Study - II

#### Challenges of Thermal Power Plants

##### Scenario

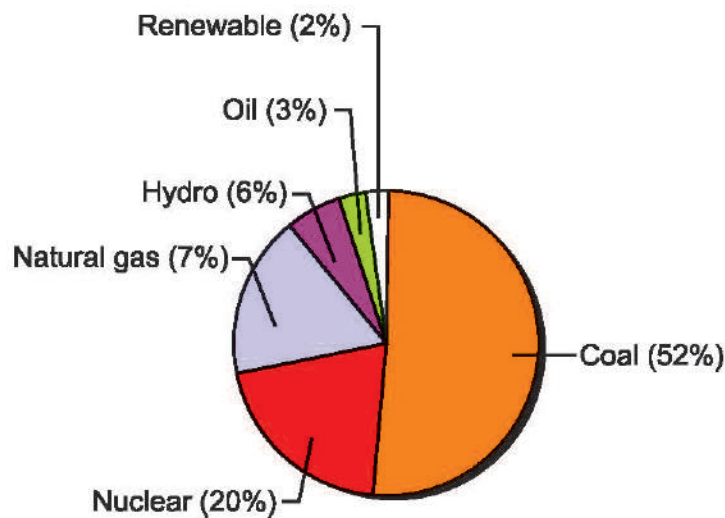
Thermal power plants recently started facing a problem in their attempt to meet the growing demands of electricity. These power plants used coal and gas as fuels which are non-renewable sources of energy. Therefore, in many countries, the fuels started to deplete causing an alarm. There was a risk of closure of the power plants and the non-availability of electricity. Therefore, some of the countries had to consider other alternatives for providing fuel to the thermal power plants. They needed other renewable sources of energy and this concern led to the increase in hydroelectric power plants, which used water as the working medium.

1. Why is the non-availability of non-renewable resources a cause of concern for various countries? (P)
2. What is the working medium that is used in hydroelectric power plants? (P)
3. Analyse other renewable alternatives that could act as fuel for power plants. (M)

## 1.7 SOURCES OF ELECTRICITY GENERATION AND THEIR CONTRIBUTIONS

Currently, the major contributors of electricity among all types of power plants are thermal power plants that use coal as fuel. These produce more than 50 per cent of the total electricity produced. The next major contributors are nuclear power plants. The disadvantage of using thermal power plants is the pollution (atmospheric and water) that they cause through chimney and sewage products.

Therefore, hydroelectric power plants are better since they are clean and do not cause pollution. Many countries are now trying to develop nuclear power plants since they produce large amounts of energy at lower costs. Figure 1.9 shows the electricity generated from various types of power plants.

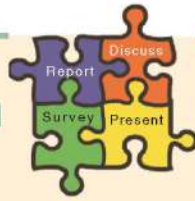


▲ Figure 1.9 Electricity Generation from Different Power Plants

**Stop**

### Check Your Progress

16. Which type of power plant is the major contributor of electricity among all power plants?
17. Why are many countries opting for nuclear power plants?



1. List the different types of power plants in the world. (P)
2. Even though the use of nuclear power plants is constantly increasing, there are some disadvantages of these power plants like health hazards. Search on the Internet and make a list of such possible health hazards with reference to the current situation in Japan. (P)
3. Search on the Internet and write an essay on wind power plants. (M)



### Case Study - III

#### Survey on Contribution of Power Plants

##### Scenario

A survey was conducted by an international power agency. The survey tried to find the percentage of the contribution of different types of power plants in the production of power. It was seen that 52 per cent of the total energy was produced by coal-fired thermal power plants. Nuclear and natural gas power plants followed at 20 and 17 per cent, respectively. The contribution of renewable resources was only 2 per cent. The increasing use of coal-fired thermal power plants is an issue of concern. The department prepared a list of the disadvantages of using coal-fired plants, which are as follows:

- ▶ They cause air and water pollution.
- ▶ They use coal as the fuel, which is a non-renewable resource.
- ▶ The combustion of coal produces  $\text{CO}_2$ , which is a harmful gas and it also adds to the greenhouse effect.

Now, this agency is trying to make all the countries aware of these harmful consequences so that they start using renewable and eco-friendly alternatives.

1. What was the subject of the recent survey done by the international power agency? (P)
2. List the disadvantages of using thermal power plants having coal as fuel. (P)
3. Make a list of all renewable and eco-friendly alternatives of power generation. (P)
4. Do you think nuclear fuel will be a better alternative to coal-fired thermal power plants? Justify your answer. (M)

## 1.8 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ In a thermal power plant, the prime mover is the steam turbine. Water, when heated, turns into steam and spins a steam turbine which drives an electrical generator to produce electricity.
- ▶ The two types of turbines used in power plants are the condensing and back-pressure turbines. In the condensing turbine, the exhausted steam from the prime mover changes to liquid while in the back-pressure turbine, the exhausted steam from the liquid is used for the process of work.
- ▶ The amount of heat required to turn saturated water into saturated steam is called latent heat of vapourization and the heat required to turn saturated steam to saturated water is called latent heat of condensation.
- ▶ The three types of steam are wet, dry and saturated steams. The type of steam depends upon the presence of liquid and temperature.
- ▶ Efficiency of a thermal unit is defined as the ratio of output to input.
- ▶ Hydroelectric plants use the energy of water to drive the turbine.
- ▶ Thermal power plants generate the highest amount of energy among all types of power plants.

## 1.9 KEY TERMS

- ▶ **Turbine:** An engine that extracts energy from steam and converts it into useful work
- ▶ **Flow path:** Refers to the connected sequence of nodes that define the path of execution for the flow

## 1.10 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Water and steam constitute the working medium in a steam power plant.
2. The two types of turbines in a steam power plant are the condensing and back-pressure turbines.
3. The advantage of the condensing operation is that it increases the amount of energy used per kilogram of steam.
4. The three types of steam are wet, dry and superheated steam.
5. The temperature of steam at which boiling or condensation occurs is called the saturation temperature.
6. Water at atmospheric pressure with a temperature below 100°C is called sub-cooled water.
7. Superheated steam is the kind of steam that is heated to a temperature greater than its saturation temperature.

8. Water heat is the amount of heat required to raise the temperature of 1 kg of water from 0°C to 100°C. Superheat is the amount of heat required to raise the temperature of 1 kg of steam from 100°C to a final temperature.
9. Sensible heat is the amount of heat required to raise the temperature of one kg of steam or water by 1°C.
10. Control valves regulate the flow of steam to the turbine.
11. A make-up water system compensates for any loss of water or steam from the cycle.
12. The overall range of efficiency for a condensing plant ranges between 23–38 per cent.
13. The formula to calculate the efficiency based on input and output quantities is as follows:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

14. Water drives the turbine of a hydroelectric power plant.
15. The mechanical energy of the water wheel can be varied by regulating the amount of water flowing through the turbine.
16. Thermal power plants that use coal as the fuel are the major contributors of electricity among all power plants.
17. Nuclear power plants produce a large amount of power at a lower cost in a lesser amount of time. Therefore, many countries are opting for them.

## 1.11 QUESTIONS AND EXERCISES

### Short-Answer Questions

1. What is a back-pressure turbine?
2. What is the total heat content of superheated steam?
3. Where is water kept in a hydroelectric power plant?

### Long-Answer Questions

1. Differentiate between condensing and back-pressure turbines.
2. 2 kg of water with an initial temperature of 20°C is heated to 100°C. Find the total heat supplied to water if the specific heat of water is 17.59 kJ/°C.
3. Why is water stored at a high altitude in a hydroelectric power plant?

# 2

## General Description of Thermal Power Plants

### STRUCTURE

- 2.0 Introduction
- 2.1 Learning Objectives
- 2.2 Energy Conversion
- 2.3 Thermal Power Plants: Major Components
- 2.4 Summary
- 2.5 Key Terms
- 2.6 Answers to 'Check Your Progress'
- 2.7 Questions and Exercises



## 2.0 INTRODUCTION

Energy appears in various forms on the Earth and can be converted from one form to another. Thermal power plants make use of this concept and adapt steam-driven energy to generate electricity. In thermal power plants, water is heated, which turns into steam and spins a steam turbine. It is this turbine which then drives an electrical generator.

In this lesson, you will learn about the general working of thermal power plants.

## 2.1 LEARNING OBJECTIVES

After going through this lesson, the trainee should be able to:

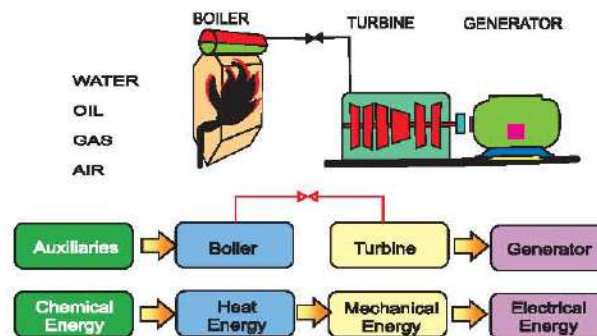
- ▶ Understand the concept of energy conversion
- ▶ Know the major components of thermal power plants

## 2.2 ENERGY CONVERSION

In a thermal power plant, the chemical energy of fuels (such as oil, coal and gas) is used to obtain electricity. In this process, conversion of energy takes place over three stages, which are as follows:

- ▶ Initially, the fuel has chemical energy in it, and by burning it in a boiler, the chemical energy is converted to thermal energy.
- ▶ Next, the thermal energy is converted to mechanical energy by rotating a turbine rotor.
- ▶ Finally, the mechanical energy is converted to electric energy by rotating a generator.

Figure 2.1 shows the process of energy conversion.



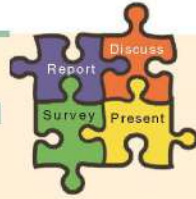
▲ Figure 2.1 Process of Energy Conversion in Thermal Power Plants

Stop

### Check Your Progress

1. What is the main source of energy in thermal power plants?
2. Name the final form of energy that is produced as the output of a thermal power plant.

## Classroom



## Activities

1. Invite a guest lecturer to talk about the conversion of energy taking place in a thermal power plant. Take notes on the same. (P)
2. Make a PowerPoint presentation on the various components of power plants showing each stage of energy conversion. (D)

### 2.3 THERMAL POWER PLANTS: MAJOR COMPONENTS

The purpose of power plants is to produce electricity and about 80 per cent of the power (in distribution) is generated at conventional steam plants. As you already know, thermal power plants use the chemical energy of fossil fuels such as coal, oil or natural gas to produce electrical energy by using the following components:

- ▶ **Boiler:** Here the heat is added to the water to produce superheated steam.
- ▶ **Turbine:** The expansion of steam takes place here.
- ▶ **Condenser:** This part condenses the exhaust steam back to water.
- ▶ **Pump:** It is used to pump the water back to the boiler.
- ▶ **Feedheaters:** Heat of the extraction steam is used to increase the temperature of the feedheater. Feedheaters can be classified into low and high-pressure feedheaters.

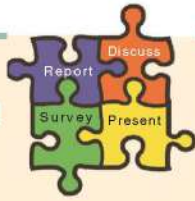
All these components need to be in proper condition and have to be maintained regularly. This is done to ensure that the thermal power plants run efficiently. Faulty equipment in the plant can lead to wastage of essential resources and may even cause major accidents.

**Stop**

#### Check Your Progress

3. What is the percentage of electricity produced at conventional steam power plants?
4. List the main components of steam power plants.

## Classroom



## Activities

1. Using the Internet, look for a picture that shows the four basic parts of a thermal power plant. Show it to your class. (P)
2. Discuss the contribution of electrical energy by various types of power plants in the Middle East. Present the same as a graph to your class. (M)
3. Visit the power plant in your institute, analyse its parts and prepare a report on how each part is integral to the working of the plant. (D)

### 2.4 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ Thermal power plants are used to produce electricity. They contribute 80 per cent of the total energy generation.
- ▶ In power plants, chemical energy of fuel is converted to thermal energy and then thermal energy is converted to mechanical energy, and finally mechanical energy is converted to electrical energy.
- ▶ The main components of thermal power plants are turbine, boiler, condenser, pump and feedheater.

### 2.5 KEY TERMS

- ▶ **Rotor:** The non-stationary or rotating part of a mechanical device
- ▶ **Thermal power station:** A power plant where the prime mover is driven by steam

### 2.6 ANSWERS TO 'CHECK YOUR PROGRESS'

1. The main source of energy in thermal power plants is the chemical energy of fuel.
2. Electrical energy is the final form of energy that is produced as the output of a thermal power plant.
3. 80 per cent of the total electricity produced is generated at conventional steam power plants.
4. The main components of steam power plants are boiler, turbine, generator, condensate pump feedwater heater and feedwater pumps.

## 2.7 QUESTIONS AND EXERCISES

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### Short-Answer Questions

1. Name the fuels that are used in a thermal power plant.
2. How is thermal energy converted to mechanical energy in a thermal power plant?

### Long-Answer Questions

1. Describe the conversion of energy in a thermal power plant.
2. Explain the basic parts of a thermal power plant and their functions.



# 3

## Power Plant Systems and Main Components

### STRUCTURE

#### 3.0 Introduction

#### 3.1 Learning Objectives

#### 3.2 Steam and Water System

#### 3.3 Cycle of Working Medium

- 3.3.1 Compression
- 3.3.2 Heating
- 3.3.3 Expansion
- 3.3.4 Cooling

#### 3.4 Live Steam System

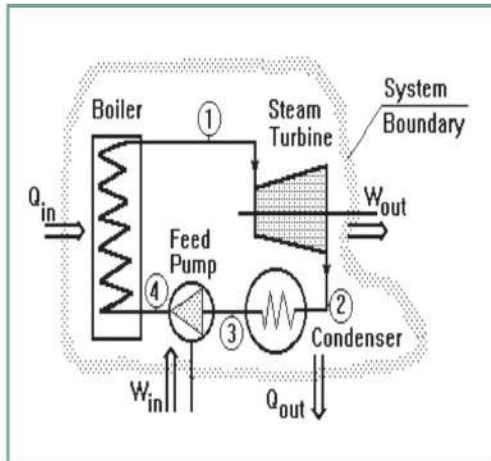
#### 3.5 Condensate and Feedwater System

#### 3.6 Summary

#### 3.7 Key Terms

#### 3.8 Answers to 'Check Your Progress'

#### 3.9 Questions and Exercises



### 3.0 INTRODUCTION

Various types of components make up a system in a thermal power plant. All of these systems have different purposes and play an important role in the functioning of power plants. Some of these systems include the steam and water system, live steam system or condensate and water system. Flow diagrams are used to depict the types of flow systems that make up a thermal power plant system.

The water and steam cycle is the most important flow and its diagrammatic flow is known as a main flow diagram. Moreover, there are other important flow diagrams, such as for turbine subsystems and electrical systems.

In this lesson, you will learn about power plant systems and their main components in detail.

### 3.1 LEARNING OBJECTIVES

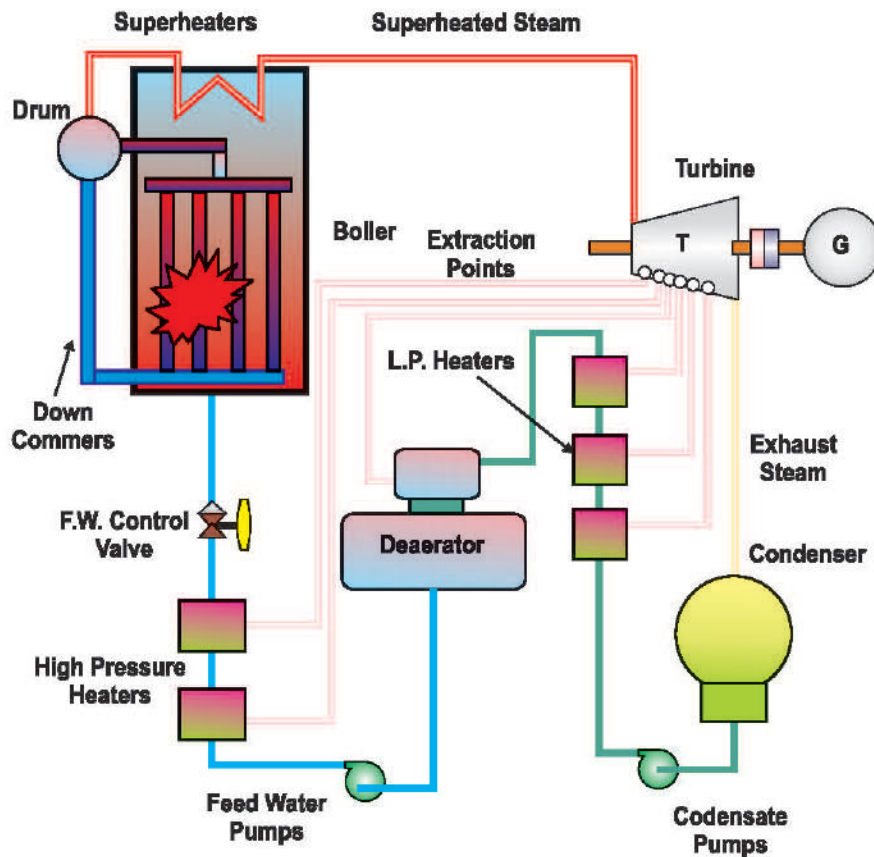
After going through this lesson, the trainee should be able to:

- ▶ Know what steam and water systems in power plants are
- ▶ Learn about the cycle of working medium, including compression, heating, expansion and cooling
- ▶ Explain what the live steam system is
- ▶ Understand the condensate and feedwater system in detail

### 3.2 STEAM AND WATER SYSTEM

In a thermal power station, water is converted into steam, which is used as a working medium. The water and steam cycle produces mechanical energy, from which electrical power is obtained.

To express and describe the flow of the cycle of water and steam and the devices in the flow, take a look at Figure 3.1 which explains the working of the thermal plant. Hereafter, we are going to study the function of each device and the state of working fluid between devices with the help of a typical main flow diagram.



▲ Figure 3.1 Steam, Condensate and Feedwater Flow Diagram

**Stop**

### Check Your Progress

1. What is the basic principle on which the working of thermal power stations is based?
2. List the main components of a thermal power plant.

## 3.3 CYCLE OF WORKING MEDIUM

The characteristic of heat engines is that they need a working medium (fluid) in order to be operated. This working medium works in a cyclic manner in a heat engine system. The operation of the heat engine system is based on four basic processes. The stages through which a working medium proceeds in a cycle are listed as follows:

- (i) Compression
- (ii) Heating
- (iii) Expansion
- (iv) Cooling

Almost all heat engines go through these stages in a cycle and only the proceeding mode of the working medium for each engine has its own variation. The four processes are shown in Figure 3.2.



▲ Figure 3.2 Cycle of Working Fluid of Heat Engine

Stop

### Check Your Progress

3. What are the basic stages through which a working medium proceeds in a cycle?
4. Name the number of steps to be followed in the heating of water in a power plant.

### 3.3.1 Compression

The working fluid (medium) in a heat cycle is compressed at the beginning of cycle. In a steam power plant, due to the rise of steam, which constitutes the main working medium, pressure is achieved. This happens mainly by the extreme increase in volume caused by conversion of water into steam.

When fluid is heated in a completely sealed or enclosed vessel, the pressure inside the vessel is raised so high as to burst out of the vessel. A fluid in a sealed vessel generates high pressure by getting heat without any expansion of volume.

Similarly, the water in a boiler generates high pressure by its evaporation. Therefore, from the stand point of working fluid operation, a boiler has two principal roles described as follows:

#### (I) Role as a pressure generating source

When water is heated in a boiler, its pressure increases gradually. This is because the volume is constant in a boiler. When the evaporation of water takes place, then this pressure increases rapidly. Thus, steam at high temperature and pressure is obtained. When the steam expands, the pressure is then released in a turbine. Thus, the boiler also plays the role of a pressure generating source.

#### (II) Role as a heat exchanging equipment

BFPs are equipped to supply water against the high pressure in the boiler. BFPs raise the pressure of water to supply it into the boiler and to operate the boiler and turbine at a pressure of 130–240 bar g and temperature of 500°C–550°C. Usually, two or three units of BFPs are equipped in parallel and are driven by electric motors or steam turbines.

### 3.3.2 Heating

Water is heated and steam is generated in five steps. The equipment used for the five stages of heating include the following:

- (i) Feedwater heaters (low pressure, high pressure and deaerator)
- (ii) Economizer
- (iii) Water walls
- (iv) Superheaters
- (v) Reheaters

The feedwater is preheated by the steam extracted from the turbine. This cycle of heating is called the regenerative cycle. Generally, this preheating is performed in two to eight stages and these stages correspond to the unit size.

Heaters equipped to handle low-pressure water from the condenser to the BFP are called low pressure heaters and deaerators. Those equipped to handle high pressure lines from the BFP to the economizer are called high pressure heaters. This complete system that starts from the condenser till before the economizer is called the preboiler system.

The high temperature and high pressure water that comes out of the final stage heater enters the economizer. The economizer can economize the heat by replacing the heat from the exhaust gas of combustion to the feedwater. This economizer is usually constructed with finned tube. Outside the economizer flow exhaust gases and inside it flows feedwater. The heat of the gas is transferred to the water through the tube and the fin.

The feedwater that is expelled out of the economizer outlet is channelized into the steam drum of the boiler. In the steam drum, the water, the steam from the water wall and the feedwater are mixed together. However, the water and steam are separated from each other by using steam separators in the steam drum.

The separated water is channelized into the water drum (bottom ring header) that is located below the boiler furnace through the down-commer pipes.

Water is distributed into the water wall tubes from the water drum by the water distributor and the lower water wall header. The water wall is made of a number of parallel tubes that surround the boiler furnace. The water is heated in the water wall tubes around the furnace as it goes up. This leads to a rise in water temperature and start of evaporation. The medium goes back into the steam drum in two phases: water and steam. This is done in a natural manner based on the difference in the density of water between the steam drum and the furnace water wall. In the case of combined or forced circulation type boiler, boiler circulation pumps on the down comer pipings can enforce and control water circulation. The water is again separated in the drum with the help of separators and the circulation process is repeated in the water wall.

Saturated steam that comes out of the steam drum is channelized into the superheaters because that steam is no longer suitable for doing any work in the turbine. In the superheater, steam is superheated up to a temperature of 510°C–550°C. This absolutely dry superheated steam is led into the turbine through the main steam piping (live steam piping) to provide energy to the turbine during the expansion process.

Generally, in a relatively large capacity plant, steam is used as thermal energy in the process of expansion. Steam is channelized into the reheat section of the boiler after a part of its thermal energy is released in a high pressure turbine. It is reheated to increase its energy. After reheating, steam is led into an intermediate pressure turbine.

Finally, almost all of the residual energy in the steam is released into the turbines while it passes through the intermediate and low pressure turbines. This system is called the reheat cycle.

**Stop**

### **Check Your Progress**

5. Name the two important roles of a boiler from the standpoint of operating a working fluid.
6. List the equipment to be used in the heating of water in a power plant.

### **3.3.3 Expansion**

The superheated steam has high pressure and high temperature and is led into the turbine. After utilizing the power of this steam, its pressure and temperature are reduced. The steam undergoes an expansion process in the turbine and its thermal energy together with its potential energy, released during expansion, changes into mechanical energy of turbine rotation.

Usually, the exhaust steam that has undergone expansion in the turbines is directly led into the condenser to cool down. However, in some cases, the exhaust steam is also led into the next equipment to be converted into mechanical energy contained in the exhaust steam. In such cases, the exhaust steam is at higher energy. This principle is followed in the utilization of exhaust steam from back pressure turbines in desalination plants.

Turbines are like large windmills that have blades around a rotor. By releasing steam on to the blades, the rotor rotates at a high speed (around 3,600 rpm). The steam expands and its temperature and pressure come down and work is done. The blades become larger and longer as the pressure comes down. Since the shafts of both the turbine and generator are connected, the rotational power of the turbine is transferred directly on to the generator. Care should always be taken to use dry exhaust steam because wet exhaust steam tends to erode turbine blades.

### 3.3.4 Cooling

The steam which is used up in the turbine is channelized into the condenser, and is condensed by cooling. The emitted latent heat is passed to the cooling circulating water. Condensation of steam takes place in a closed vessel that produces a partial vacuum because the volume of vapour is substantially reduced. On the other hand, the amount of available (or effective) heat becomes greater when the discharge pressure is lower. Therefore, the higher the vacuum of the condenser, the higher is the cycle efficiency.

The cooling water flows inside the condenser piping and the steam flows out. Such condensers are called surface type condensers and the condensed water, called condensate, is pumped out of the condenser by the condensate pumps. This is channelized into the deaerator through the preboiler system.

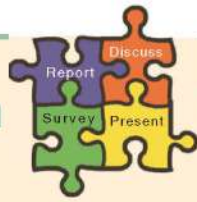
In the low pressure feedwater line, a deaerator is equipped to remove dissolved gases, such as oxygen and carbon dioxide.

**Stop**

#### **Check Your Progress**

7. Why should dry exhaust steam be used in turbines?
8. What is the role of the boiler in a power plant?

## Classroom



## Activities

1. On a visit to the power plant, identify the stages through which the working medium passes in a cycle. (P)
2. Prepare a detailed report that contains a compare and contrast study of compression and cooling. (M)



### Case Study - I

#### Ideal Working Medium

##### Scenario

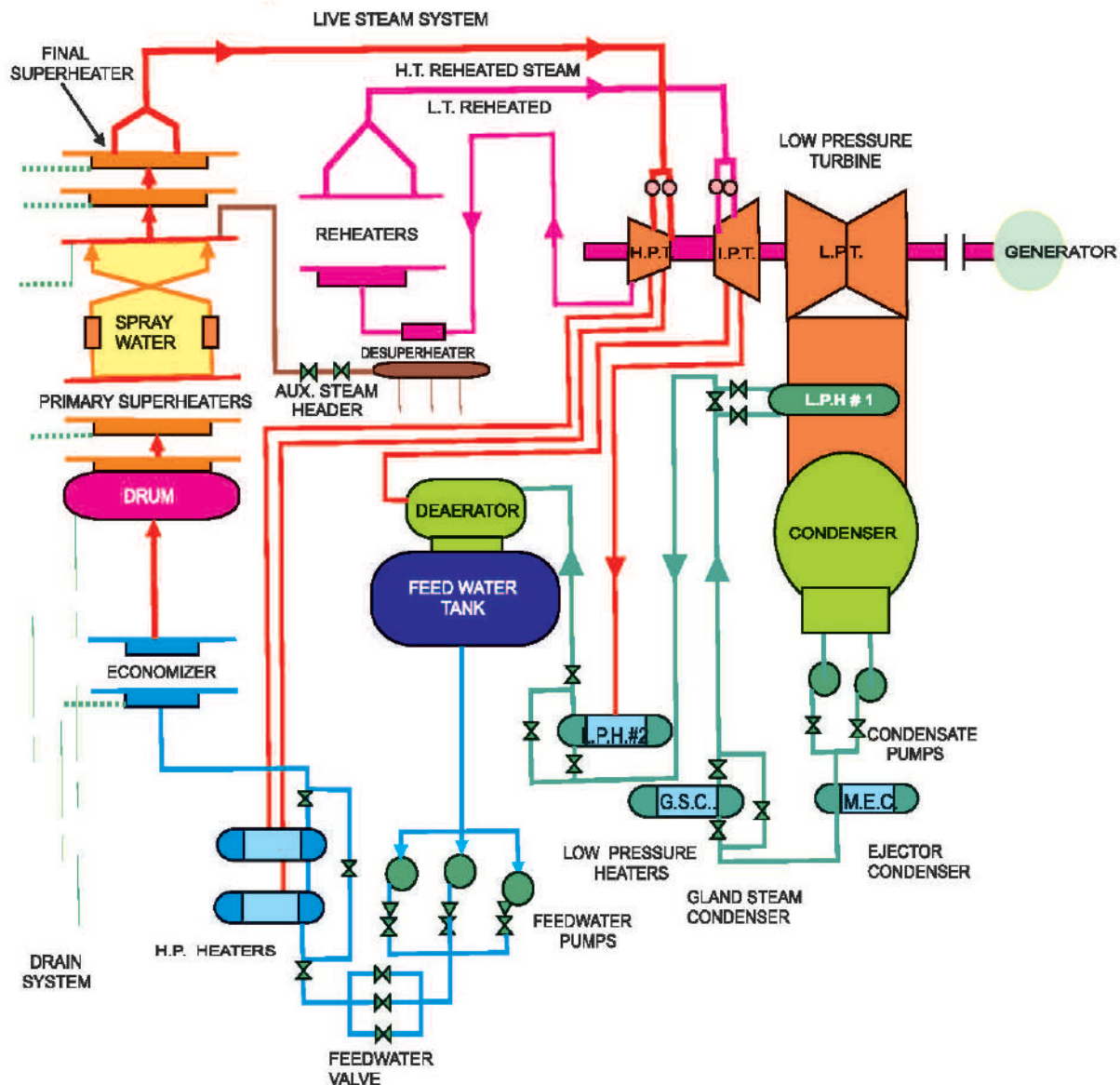
Before thermal power plants came into being, power engineers and scientists had tried for long to find out the ideal working medium that could be used. The objective was to determine which medium gave the optimum work and required minimum pump work. Since work done is equal to the integration of  $PdV$ , hence a medium should be such that it expands and its volume increases to the maximum. This is in order to get the maximum turbine work and decrease its volume to the lowest in the pump to get minimum turbine work. This is because efficiency is equal to work done by turbine minus the work done by pump divided by heat input.

Based on several deductions, it was determined that water would be the best medium because when converted into steam, its volume increases to the maximum, and when in liquid form, its volume decreases.

1. What is the formula for work done for a closed system? (P)
2. What is the relation between work and efficiency in a thermal power plant? (P)
3. On what basis can water be considered as the best working medium in a thermal power plant? (M)

### 3.4 LIVE STEAM SYSTEM

Steam is produced in the boiler, known as the main steam system. Figure 3.3 shows the transportation of steam to the high pressure turbine. The main steam system includes the cold reheat line, which returns the high pressure turbine exhaust to the boiler where the steam is reheated. The reheated steam is transported back to the low pressure turbines by the hot reheat line.



▲ Figure 3.3 Flow of Steam and Water with Reheating System

The main steam system also supplies steam to the turbine gland seal system and the air ejectors.

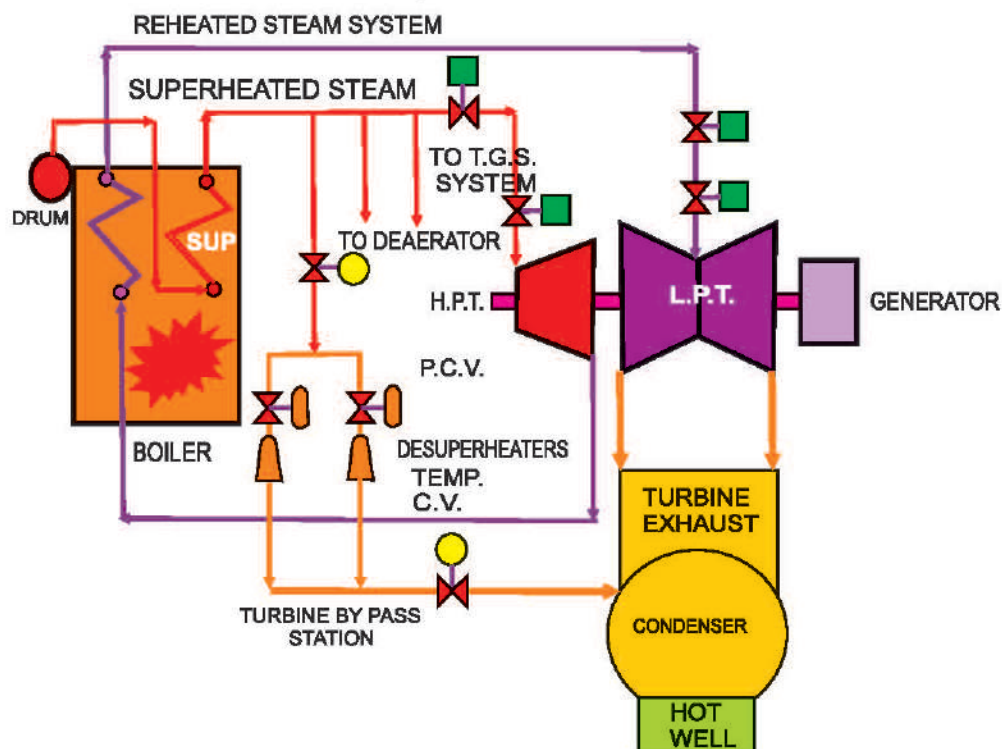
On each main steam and reheat steam line that comes out of the boiler, there is at least one safety valve. These safety valves protect the steam piping system from over pressure. In some plants, each steam line has a motor operated stop valve. This valve is used to positively isolate the steam line. Often the main steam lines are linked directly to the

turbine's stop valve and then to the steam chest. There are control valves in the steam chest, which form a part of the high pressure turbine.

The turbine stop valve is a fast closing valve that stops the flow of steam to the turbine and isolates the turbine from the steam system. The stop valve will close automatically during emergency situations, such as turbine over speed, loss of condenser vacuum or operation of any of turbine protective devices and so on. The turbine control valve regulates the speed and load of turbine by controlling the rate of flow of steam through the high pressure turbine.

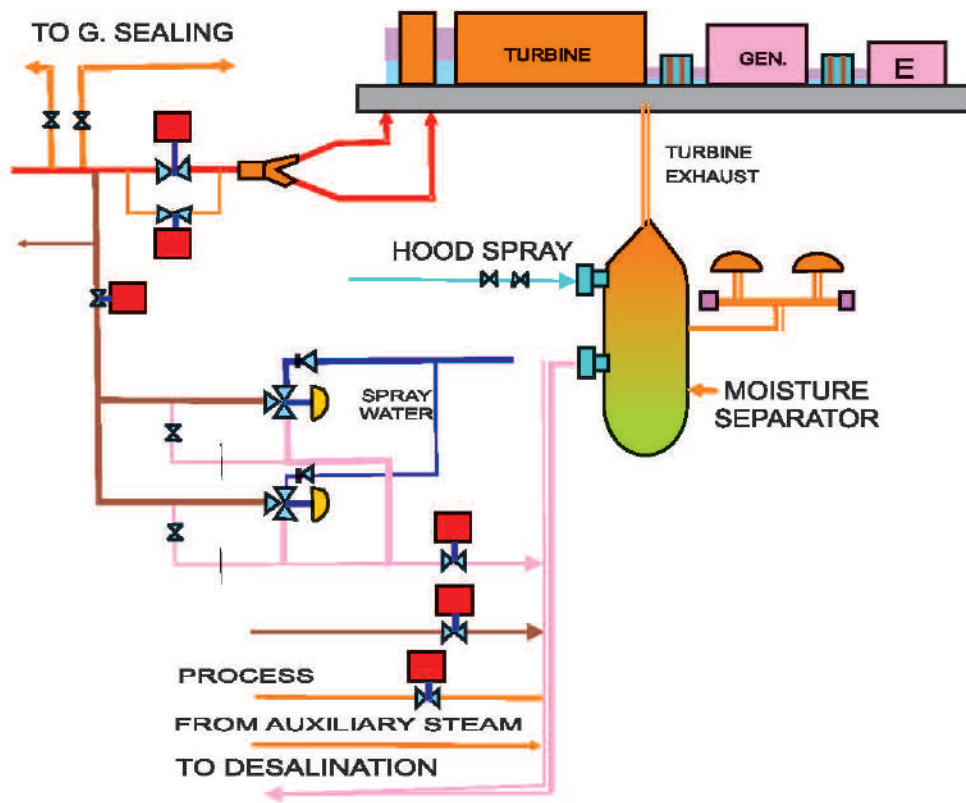
The main steam lines and the hot reheat line are long lines that run from the top of the boiler down to the turbine. These lines have many elbows and loops throughout their length to allow room for thermal expansion of the steam piping during plant start up. These not only allow for thermal expansion but also support the weight of piping.

Steam piping systems are such that they are insulated to help prevent any loss of heat as the steam passes onto the turbine. Despite that, some heat is lost; hence, some condensation does take place in the steam lines. However, even a small amount of condensation can damage the steam lines and the turbine, if it is not removed. Steam traps are installed in the steam lines to remove this condensation. These traps automatically remove water and do not allow steam to pass through the trap. Water recovered in the steam trap is returned to the condenser to conserve water (Figure 3.4).



▲ **Figure 3.4** Main Steam and Reheated Steam System for Condensing Turbine

The back-pressure turbine is a turbine in which the pressure at exhaust stage from the turbine is the saturation pressure that corresponds to the temperature desired for process work (Figure 3.5).



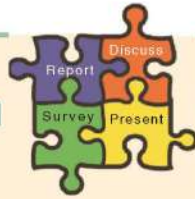
▲ Figure 3.5 Main Steam System for Back Pressure Turbine

Stop

### Check Your Progress

9. List out the advantage of safety valves.
10. What are main steam lines and hot reheat lines?
11. What are pipe hangers used for?

## Classroom



## Activities

1. Identify the following parts in SWCC's thermal power plant: (P)
  - Reheater
  - Deaerator
  - Feedwater tank
2. Visit the SWCC thermal power plant and enquire about the uses of auxiliary steam in the plant. (P)
3. Prepare a detailed report on the types of safety valves that are used for steam lines and boilers in a thermal power plant. (M)



### Case Study - II

#### Safety Measures in Power Plants

##### Scenario

In a power plant, there has been a leakage of steam. The capacity of the plant is 585 MW and it is a heavy fuel oil fired unit. This accident has left two of the workers injured and one worker dead. The injured workers mostly got severe burns on their faces and hands.

The leakage took place without any warning when the workers were surveying the pipelines. Unfortunately, the workers were not following the stipulated protection measures.

A technical committee was set up to investigate why steam leaked through the pipes. It was found that the main reason was that the couplings got weakened. This incident led the director of safety operations to put in place some important measures that have to be followed by the employees while working or surveying the pipes. These measures are listed as follows:

- Always wear the specific, coded protection uniform before handling the steam pipes.
  - Always wear a helmet that covers the face and head properly.
  - Always wear custom safety shoes with thick soles and anti-skid rubber lining.
  - The pipe lines and couplings should be subjected to regular checking once every two months.
1. What caused the steam to leak in the power plant? (P)
  2. Name any two safety measures that SWCC adheres to in case of any kind of leakages. (P)
  3. In your opinion, what are the additional precautions to be followed while inspecting a site? (M)

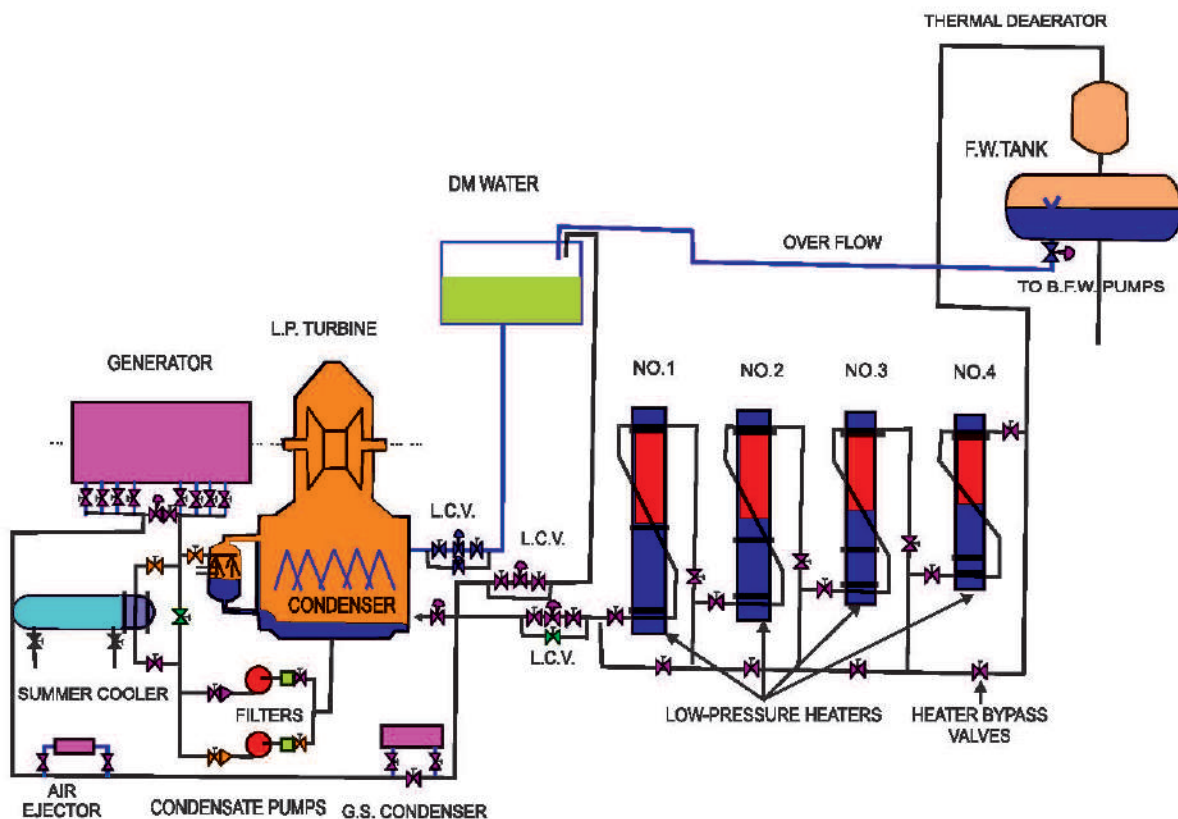
### 3.5 CONDENSATE AND FEEDWATER SYSTEM

The condensate water pumped by the condensate pump is primarily led into the air ejector and gland steam condenser. The deaerator is placed at a height above the ground in order to provide sufficient suction head to avoid steaming at the inlet of the BFP. If the suction pressure falls below vapour pressure corresponding to prevailing temperature, the steaming starts which results in cavitation.

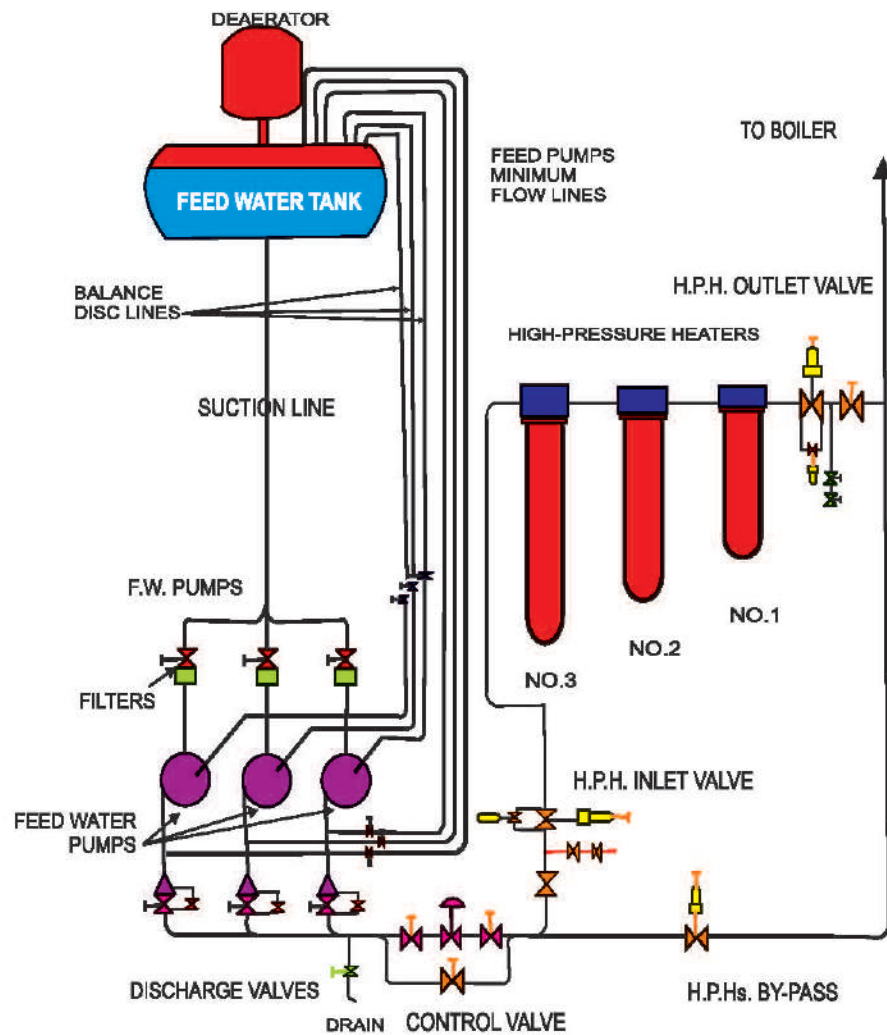
After passing through the air ejector and gland condenser, it flows through several low-pressure feedwater heaters. Inside these heaters, it obtains heat from the turbine exhaust and extracting steam. After this, it enters the deaerator.

The function of the deaerator is to remove dissolved gases, such as oxygen and carbon dioxide, from condensate water. After deaeration, the stored condensate water in the tank is channelized into the suction of the BFP and discharged into the high pressure feedwater line. It enters the boiler after passing through several stages of high pressure feedwater heaters.

Thus, the water flows in a cyclic manner repeatedly to perform its role as the working medium in a power plant. Condensate and feedwater system are shown in Figures 3.6 and 3.7.



▲ Figure 3.6 Condensate Water System



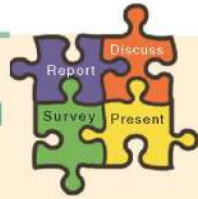
▲ Figure 3.7 Feedwater System

**Stop**

### Check Your Progress

12. What is the use of a feedwater heater?
13. Define 'condensate'.
14. What is the function of a deaerator?

## Classroom



## Activities

1. Illustrate the feedwater system of a thermal power plant on the class board. (P)
2. Explain the flow of condensate water in a thermal power plant. (P)
3. Prepare an energy balance and demonstrate how the efficiency of a power plant can be improved. (M)



### Case Study - III

#### Technology in a Cogeneration Plant

##### Scenario

Recently, in a thermal power plant, a new advanced technology system is being used in which the exhaust gases from the turbine are used for performing heating operations or to do pass-out work. This means that the system is generating power and doing pass-out work simultaneously. This is an example of a cogeneration plant. The advantages of such plants are listed as follows:

- ▶ The waste energy, of exhaust steam, can be used for pass-out work, thus increasing efficiency.
  - ▶ Such plants can generate power and do pass-out work at the same time.
1. What is a cogeneration plant? (P)
  2. Name one advantage of a cogeneration plant. (P)
  3. Do you know of any cogeneration power plants? Name any one such plant. (M)

### 3.6 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ In a thermal power station, water is converted into steam, which is used as a working medium.
- ▶ The characteristic of heat engines is that they need a working medium (fluid) in order to operate. This working medium works in a cyclic manner in a heat engine system.
- ▶ The stages through which a working medium proceeds in cycle are compression, heating, expansion and cooling.
- ▶ In a steam power plant, due to the rise of steam, which constitutes the main working medium in a steam power plant, pressure is achieved. This is mainly by the extreme increase in volume caused by conversion of water into steam.
- ▶ Water is heated and steam is generated in five steps. The equipment used for the five stages of heating are feedwater heaters, economizer, water walls, superheater and reheaters.
- ▶ Heaters equipped handle low pressure water from the condenser to the BFP are called low-pressure heaters and deaerators. Those equipped to handle high pressure lines from the BFP to the economizer are called high pressure heaters.
- ▶ Saturated steam that comes out of the steam drum is channelized into the superheaters to improve the amount of work generated by it.
- ▶ Usually, the exhaust steam that has undergone expansion in the turbines is directly led into the condenser to cool down. But in some cases, the exhaust steam is also led into the next equipment to be converted into mechanical energy contained in the exhaust steam.
- ▶ The steam which has been used up in the turbine is channelized into the condenser, which is condensed by cooling. The emitted latent heat is passed to the cooling circulating water.
- ▶ The main steam lines and the hot reheat line are long lines that run from the top of the boiler down to the turbine. These lines have many elbows and loops throughout their length to allow room for thermal expansion of the steam piping during plant start up.
- ▶ Condensate water is pumped out of the hot well at the bottom of the condenser by condensate pumps to the thermal deaerator.

### 3.7 KEY TERMS

- ▶ **Back pressure turbine:** A turbine in which the pressure at exhaust stage from the turbine is the saturation pressure that corresponds with the temperature desired for process work
- ▶ **Cold reheat line:** A part of the main steam that returns the high pressure turbine exhaust to the boiler where the steam is reheated
- ▶ **Regenerative cycle:** The process of heating where the feedwater is preheated by the steam extracted from the turbine
- ▶ **Reheat cycle:** The system where almost all of the residual energy in steam is released into the turbines while it passes through the intermediate and low pressure turbines
- ▶ **Turbine stop valve:** A fast closing valve that stops the flow of steam to the turbine and isolates the turbine from the steam system
- ▶ **Gland steam condenser:** A part of the power plant that utilizes heat associated with the steam used for gland sealing to heat the condensate water
- ▶ **Air ejector:** A part of the condensate water system that is used to remove noncondensable gases from the condenser and the heat contained in them is used to heat the condensate water

### 3.8 ANSWERS TO 'CHECK YOUR PROGRESS'

1. The basic principle based on which thermal power stations work is that water is converted into steam which is used as a working medium. This water and steam cycle produces mechanical energy, from which electrical power is obtained.
2. The main components of a thermal power plant are listed as follows:
  - ▶ Boiler
  - ▶ Turbine
  - ▶ Condenser
  - ▶ Pump
  - ▶ Generator
  - ▶ Heater
  - ▶ Deaerator
3. The four basic stages that a working medium proceeds through are listed as follows:
  - ▶ Compression
  - ▶ Heating
  - ▶ Expansion
  - ▶ Cooling
4. The heating of water in a power plant is done in five stages.
5. The two main roles of a boiler from the point of operating a working fluid are listed as follows:
  - (i) Role as a pressure generating source
  - (ii) Role as a heat exchanging equipment

6. The equipment to be used in the heating of water in a power plant are listed as follows:
  - ▶ Feedwater heaters
  - ▶ Economizers
  - ▶ Water walls
  - ▶ Superheaters
7. Care should always be taken to use dry exhaust steam in turbines because wet exhaust steam tends to corrode turbine blades.
8. The role of a boiler is to act as a pressure generating source and heat exchanging equipment.
9. Some of the advantages of using safety valves are as follows
  - ▶ To protect steam piping from over pressure
  - ▶ To positively isolate the steam line
10. Main steam lines and hot reheat lines are long lines that run from the boiler down to the turbine. These lines allow room for thermal expansion of steam piping during plant start ups.
11. Pipe hangers are designed to allow for thermal expansion as well as to support the weight of piping systems in power plants.
12. A feedwater heater is used to preheat the water delivered to a steam generating boiler. Preheating the feedwater reduces the irreversibilities involved in steam generation, which thus improves the efficiency of systems.
13. A condensate is a liquid formed when a vapour is cooled to its saturation limit.
14. The function of a deaerator is to remove dissolved gases, such as oxygen and carbon dioxide, in condensate water.

### 3.9 QUESTIONS AND EXERCISES

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#### Short-Answer Questions

1. What does the circulating water flow diagram represent?
2. List the uses of boiler feedwater pumps.
3. Where does the condensate water go after it is pumped by the condensate pump?

#### Long-Answer Questions

1. Discuss the function of the economizer.
2. Describe the working of a feedwater system.
3. Explain the conversion of energy during expansion in turbines of thermal power plants.

# 4

## Power Plant Cycles - Boiler Blowdown System

### STRUCTURE

#### 4.0 Introduction

#### 4.1 Learning Objectives

#### 4.2 Boiler Blowdown System

#### 4.3 Boiler Drains and Venting System

- 4.3.1 Drum Vents
- 4.3.2 Down-commer Drains
- 4.3.3 Primary Superheater Drains
- 4.3.4 Secondary Superheater Vents
- 4.3.5 Secondary Superheater Drains
- 4.3.6 Tertiary Superheater Drains
- 4.3.7 Gauge Glass Drains

#### 4.4 Summary

#### 4.5 Key Terms

#### 4.6 Answers to 'Check Your Progress'

#### 4.7 Questions and Exercises



## 4.0 INTRODUCTION

Since long, power plant engineers have faced the problem of precipitation of concentrated solid particles at drum bottom, which leads to loss of heat transfer resulting in loss of energy. Boiler blowdown is the process of removal of water from a boiler. Its purpose is to control boiler water parameters within prescribed limits for minimization of scale, corrosion, carryover and other specific problems. This process is also used to remove suspended solids present in the system. This lesson will deal with the boiler blowdown system. The use, type and location of drains and vents in boilers will also be discussed in this lesson.

## 4.1 LEARNING OBJECTIVES

After going through this lesson, the trainee should be able to:

- ▶ Understand the problems with boiler blowdown
- ▶ Solve the problems of boiler blowdown system
- ▶ Learn about boiler drains and venting system

## 4.2 BOILER BLOWDOWN SYSTEM

Boiler blowdown systems are installed in boilers to control, schedule or manage blowdown maintenance needs. Generally, these systems are fitted at the lowest point of the boiler where the insoluble contaminate usually accumulates. Typically, industrial boilers are flushed through the blowdown fittings daily. The boiler blowdown system serves the purpose of handling and disposing plant drains and vents and relieving excessive steam pressure from boilers.

Blowdown is usually continuous, but it is generally used during boiler start up and emergency cases. The continuous blowdown route is from the drum to the blowdown flash vessel via a remote/manual motorized modulating valve. An emergency bypass continuous blowdown route is provided upstream of the motorized valve via another remote/manual motorized modulating valve to the blowdown tank. Samples of this drum water are taken continuously from this blowdown pipe. The drum start-up blowdown for transient water level swelling is provided via a remote/manual motorized modulating valve to the blowdown tank. This valve can be utilized during the period of the drum pressure up to 1 bar g.

The condensate in the blowdown flash vessel is transferred under level control by pressure difference to the blowdown tank. The tank is vented to the atmosphere, and the condensate is discharged to the cash basin (cooling sump) in which seawater spray is introduced for cooling purpose.

During normal operation, the blowdown rate of each boiler must be controlled at 1 per cent of the boiler evaporation by adjusting continuous blowdown control valve at maximum continuous rating (MCR). During the start up operation, flash steam must be discharged to the main vent by opening the vent valve. Flash steam must be restored to the deaerator after it starts operating.

A bypass line is provided for blowdown line, and it is connected to the blowdown tank directly. The bypass line is also provided with a control valve and used during maintenance of continuous blowdown control valve.



### Check Your Progress

1. What is the boiler blowdown process?
2. What is the source of samples of drum water?
3. How is a blowdown route provided?
4. When do we use a control valve of bypass line?

## Classroom



## Activities

1. Compare the continuous blowdown route to the emergency bypass continuous blowdown route and present the findings in your class. (M)
2. Invite a guest lecturer to speak on boiler blowdown system and their uses in power plants. (D)



### Case Study - I

#### Failure of Power Plant

##### Scenario

A newly built power plant stopped working within a few months. A committee of engineers and technicians was formed to find out the cause of failure. The committee concluded that the superheater in the boiler working under low efficiency. The reasons behind the failure were as follows:

- ▶ Scale formation owing to salt deposition inside the tube
  - ▶ Overheating as a result of reduction of heat absorption caused by formation of scales
  - ▶ Failure of tube (superheater) owing to overheating and rupture
1. What was the result of overheating of superheaters? (P)
  2. Why did scale formation take place? (M)

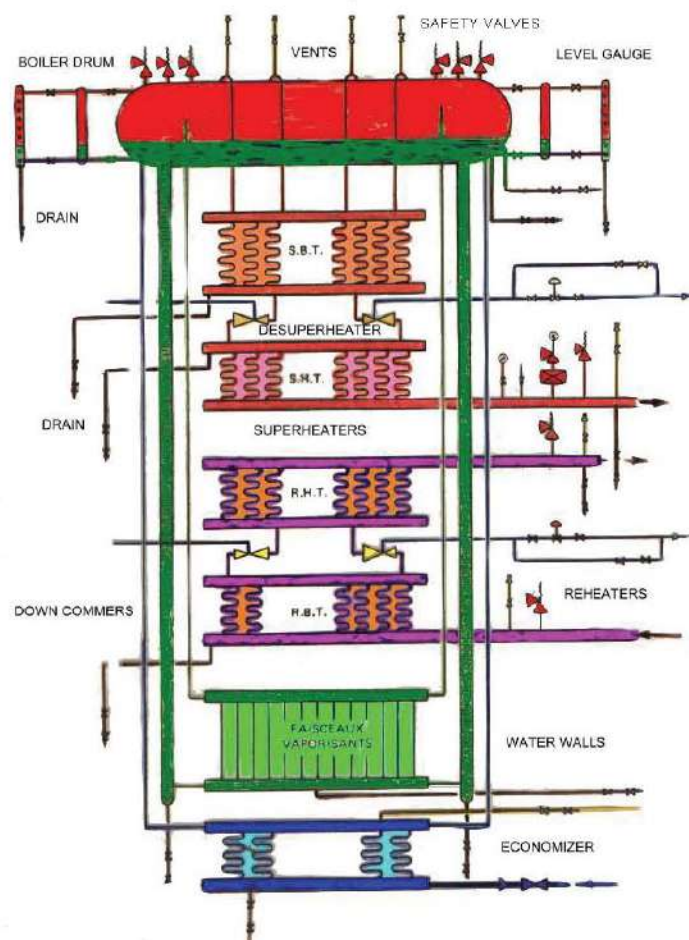
### 4.3 BOILER DRAINS AND VENTING SYSTEM

Although almost never used while the unit is online (the gauge glass drain is a major exception), the vent and drain system of the fluid cycle becomes very important during unit start up.

The furnace down comer drum system, the economizer and the superheaters all have vents at their high points and drains as low as possible. As a drain cannot be attached to each individual tube loop, the pendant type sections have drains on the bottom of their inlet and outlet headers. Most of the vents and drains are on 5 cm lines with manual valves in them (Figure 4.1). The vents are generally used to bleed air out of the system either when a hydrotest is done or when the unit is fired up.

Drains are used to drain the water out of the system for various purposes, listed as follows:

- ▶ Control of drum swell
- ▶ Maintain water chemistry
- ▶ Maintenance
- ▶ Prevention of water hammer (a hammering sound in the pipe containing water) or carryover of water to the turbine
- ▶ Bleed the steam off the system
- ▶ Heat boiler tubes evenly



Stop

#### Check Your Progress

5. What is the location of vent and drain in an economizer?
6. What is the use of down-commer drain?
7. What is the use of a vent and drain?

▲ Figure 4.1 Boiler Drains and Venting System

### 4.3.1 Drum Vents

When the unit is fired up from zero pressure, drum vents are opened until 2-bar drum pressure is reached. This will bleed any air out of the drum.

### 4.3.2 Down-commer Drains

Down commer drains are used to control drum swell and drain the entire furnace for maintenance.

### 4.3.3 Primary Superheater Drains

Primary superheater (PSH) drains form the line that comes from the convection pass enclosure header—the lowest point in the superheater. It drains the PSH banks. It is partially opened during start ups and left open until the unit is synchronized. It drains out any condensate that may accumulate in the PSH. During the first few hours of firing, there may be enough heat in the furnace to produce steam, yet the PSH will be cool enough to condense this steam.

This line is on the PSH inlet header. It drains out any condensate in the drum to the PSH inlet header supply tubes and the convection pass PSH bank.

### 4.3.4 Secondary Superheater Vents

Secondary superheater (SSH) vents form the line on the SSH outlet header. Either this vent or the SSH drain is opened when the unit is fired, but the turbine is rolled to maintain some flow through the SSH.

This helps the SSH to warm up evenly. If sufficient steam flow is not passed through SSH during initial firing, steam temperature swings may be caused when the turbine is rolled.

### 4.3.5 Secondary Superheater Drains

SSH drains lie on the SSH outlet drain on the SSH outlet header. Either this drain or the SSH vent is opened when the unit is fired before the turbine is rolled.

### 4.3.6 Tertiary Superheater Drains

Tertiary superheater (TSH) drains form the lines on the TSH inlet and outlet headers. As with the SSH inlet and outlet vents and drains, this line must be opened during initial firing of the boiler for equalizing steam temperature and drying TSH banks.

### 4.3.7 Gauge Glass Drains

The gauge glass is the most dependable indication of drum level. Briefly opening and closing its drain will cause the level to drop out of the glass and then reappear. This proves that the glass is indicating properly. This will also clean the glass and make reading easier. Because of the importance of the glass to unit operation, the gauge glass drain should be used on a regular (once a day and before each startup) basis to verify the proper functioning of the glass.



1. Draw the diagram of a boiler showing boiler drain and vents. (P)
2. In groups of four, compare the drain superheater to the secondary superheater. (P)
3. Analyse how the opening of drains helps in heating the system evenly. (M)



## Case Study - II

### Resurrecting a Power Plant

#### Scenario

In 1965, an MNC acquired a 3200-MW thermal power plant. The plant was going through severe losses. Several economists were against this deal since they thought it was not worth buying the power plant, which was already suffering heavy losses. However, the MNC was very much confident that they could extract profits from this plant.

Since it was an old plant, the company constituted an enquiry to find out why the power plant incurred severe loss even though there was a huge demand of power in the country.

The reasons for the poor performance of the plant were found to be as follows:

- ▶ Old equipment
- ▶ Negative attitude of the employees towards work
- ▶ Formation of scales in boiler superheaters

The scales formed an insulation layer on the tubes and affected heat transfer resulting in less efficiency.

On the recommendation of the committee, the following steps were taken to resolve these problems:

1. Old equipment was totally changed to new, and new technology was used.
2. Every employee was given a responsibility, and the status of work done had to be submitted on a daily basis.
3. Boiler blowdown was installed, which reduced formation of scales on tubes. This increased heat exchange and, finally, increased efficiency.

As a result, the efficiency of the power plant increased, and the power plant started giving profits within a few days.

1. What was the result of the implication of the new steps taken in the power plant? (P)
2. What were the reasons of poor performance of the plant? (P)
3. Why was the old equipment changed? (M)

## 4.4 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ In a thermal power plant boiler, concentrated solid particles precipitate at the bottom of the drum. These are removed by opening of blowdowns, causing loss of energy and decrease in efficiency.
- ▶ An emergency bypass of continuous blowdown route is provided upstream of the motorized valve, via another remote/manual motorized modulating valve, to the blowdown tank.
- ▶ Boiler blowdown is applied to prevent scale formation and accumulation debris.
- ▶ Boiler blowdown system is used for handling and disposing plant drains and vents.
- ▶ The vents are generally used to bleed air out of the system either when a hydrotest is done or when the unit is fired up.

## 4.5 KEY TERMS

- ▶ **Blow down:** Refers to the process of removal of solid or liquid solution from a vessel
- ▶ **Bypass line:** A pipe connection around a valve or other control mechanism installed to permit passage of fluid through the line while adjustments or repairs are being done on the control
- ▶ **Water hammer:** A hammering sound in the pipe containing water

## 4.6 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Boiler blowdown is the process of removal of water from a boiler. Its purpose is to control boiler water parameters within prescribed limits for minimization of scale, corrosion, carryover and other specific problems.
2. The source of samples of drum water is the blowdown pipe.
3. A blowdown route is provided from the drum to the blowdown flash vessel via a remote/manual motorized modulating valve.
4. Control valves of bypass line are used during maintenance of continuous blowdown.
5. Vents are located at high points of the economizer and drains are located as low as possible.
6. Down-commer drains are used to control drum swell and to drain the entire furnace for maintenance.

7. Drains and vents are used for the following purposes:
- ▶ To bleed air out of the system either for a hydrotest or as the unit is fired up
  - ▶ To drain water out of the system
  - ▶ To bleed steam off the system
  - ▶ To maintain water chemistry

## 4.7 QUESTIONS AND EXERCISES

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### Short-Answer Questions

1. What happens to the drain in a blow tank?
2. Name the three drain headers.
3. How is the condensate in the blowdown flash vessel transferred?
4. When and why is the SSH drain opened?

### Long-Answer Questions

1. Why is blowdown necessary?
2. How is blowdown rate controlled?
3. Why should TSH line drains be opened during initial firing of boilers?
4. What will be the result if sufficient steam flow is not passed through SSH during initial firing?

# 5

## Power Plant Cycles - Air and Flue Gas System

### STRUCTURE

#### 5.0 Introduction

#### 5.1 Learning Objectives

#### 5.2 Types of Draft Systems

5.2.1 Natural Draft System

5.2.2 Mechanical Draft System

#### 5.3 Air and Flue Gas System with Gas Recirculation Fans

#### 5.4 Sealing and Cooling Air Systems

5.4.1 Providing Combustion Air for Ignitors

5.4.2 Sealing the Gas around the Burners

5.4.3 Providing Air for Soot Blowers

#### 5.5 Summary

#### 5.6 Key Terms

#### 5.7 Answers to 'Check Your Progress'

#### 5.8 Questions and Exercises



## 5.0 INTRODUCTION

This lesson explains the draft system, which is used to supply air required for the combustion of fuel in a boiler furnace and to exhaust the resultant combusted flue gas into the atmosphere after the heat recovery through a stack. The passage through which air and gas pass is called a duct. A duct system is also known as ductwork.

When the air and gas flow in the ductwork, as in the case of water, draft loss (pressure loss) occurs. Therefore, we must pressurize the air by some means at a proper point of the flow. For this purpose, the draft system is generally equipped with fans. Such a system is called a mechanical draft system.

## 5.1 LEARNING OBJECTIVES

After going through this lesson, the trainee should be able to:

- ▶ Identify the various types of draft system
- ▶ Describe the air and flue gas system with gas recirculation fans
- ▶ Understand how sealing and cooling air systems work

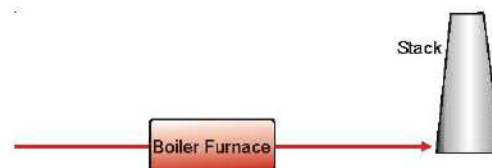
## 5.2 TYPES OF DRAFT SYSTEMS

There are generally two kinds of draft systems:

- ▶ Natural draft system
- ▶ Mechanical draft system

### 5.2.1 Natural Draft System

The natural draft system is without FDFs and ID fans. It uses a chimney and the draft is produced by the density difference between atmospheric air and hot gas in the chimney. In this system, the gas draft in the boiler furnace, in which the fuel is combusted, is maintained at a pressure which is a little lower than the atmospheric pressure (about a few millimeters of water column) during operation. Pressure is provided by the natural draft of the chimney.



▲ Figure 5.1 Natural Draft System

### 5.2.2 Mechanical Draft System

The mechanical draft system has three kinds of draft systems. They are:

#### 1. Balanced Draft System

The balanced draft system is a combined draft system—of a forced draft (FD) by a fan (FDF) and an induced draft (ID) by an ID fan. In this case, the gas draft in the boiler furnace, in

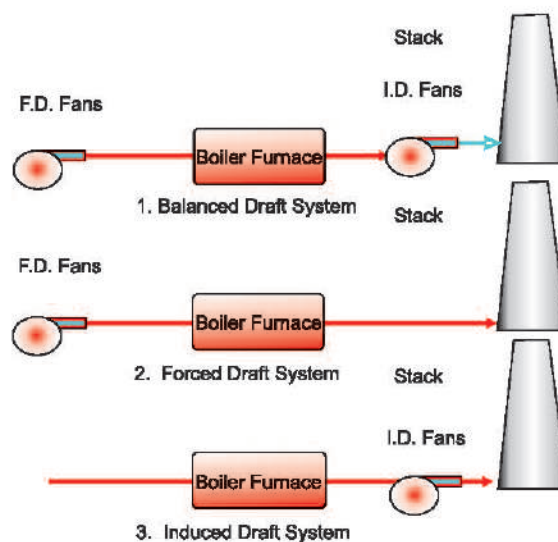
which the fuel is combusted, is maintained at a pressure which is a little lower than the atmospheric pressure during operation (about a few millimeters of a water column).

## 2. Forced Draft System

The FD system has a FDF without an ID fan. In this case, the gas draft in the boiler furnace is maintained at a pressure higher than the atmospheric pressure (about a few hundred millimeters of a water column).

## 3. Induced Draft System

In this draft, the furnace is maintained at a pressure much lower than the atmospheric pressure. The fan is placed after the furnace.



▲ **Figure 5.2** Balanced, Forced and Induced Draft Systems

## Functions of chimney

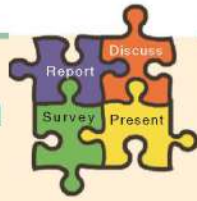
The chimney used in the draft system performs the following functions:

- ▶ Assists the fans in overcoming loss of pressure
- ▶ Helps the effluent gas disperse into the atmosphere at a sufficient height to minimize atmospheric pollution

**Stop**

### Check Your Progress

1. What are the various types of draft system?
2. Which draft system does not require a fan?
3. What is a natural draft system?



1. Bring a soft drink in a glass to class. Try drinking it with a straw. Now observe the water column suction pressure created in it. (P)
2. Compare a natural draft system with a FD system. (M)



## Case Study - I

### Using Chimneys to Fight the Chilling Cold

#### Scenario

In cold regions like Antarctica, the ground is deep with snow and the temperature is quite below zero °C – with a wind chill factor well below zero. Harsh climatic conditions make the life of the inhabitants difficult. To deal with intense cold conditions, people make a proper arrangement to burn fire so that they can use the heat produced to protect their body from the chilling cold.

The fireplace is provided with a chimney and a fan. The chimney works on the principle of density difference. A combustible gas is hot due to which its density is less than that of atmospheric air. So, being lighter in density, it will tend to rise. The chimney provides the passage for combustible gases and helps in the release of combustible gases into the atmosphere.

For the proper combustion of fuel and wood, proper supply of oxygen is necessary. However, as combustion begins, the carbon dioxide and gas produced surrounds the combustion parts and makes a layer due to which the supply of surrounding oxygen stops. To avoid this problem, a fan is given which provides turbulence, removes the carbon layer and helps in the proper combustion of fuels.

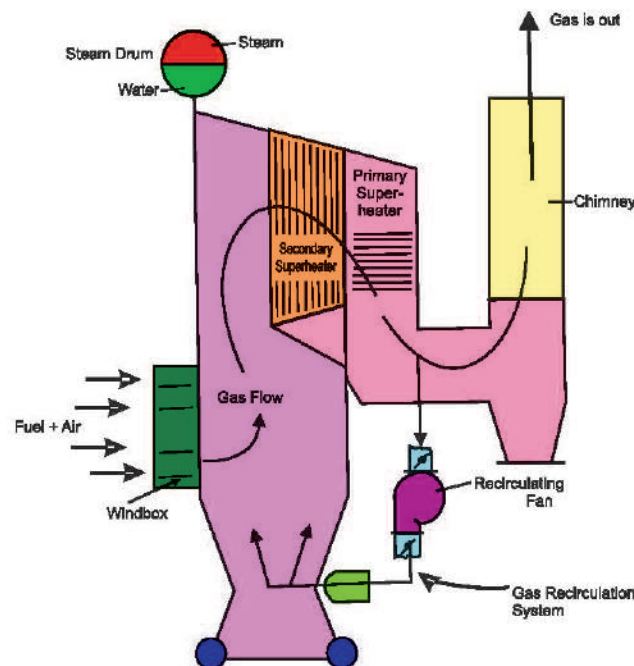
1. What do the people in cold regions do to beat the chill? (P)
2. What is the use of a chimney in the fireplace? (P)
3. Why is a fan required in the fireplace ? (M)

### 5.3 AIR AND FLUE GAS SYSTEM WITH GAS RECIRCULATION FANS

Now, you will learn about air and gas flow with the help of an air and gas flow diagram in case of a FD system (Figures 5.2 and 5.3).

When the quantity of air required is in excess, the flow duct is divided into two series. Air is induced at first from the atmosphere into the suction of the FDF which is used to cover the draft loss in the whole draft system. The air from FDF goes into an air preheater (APH). An APH is a kind of heat exchanger to transfer the heat of gas. It is equipped to raise the plant efficiency by reducing the heat emitted out of the plant and to raise the combustion efficiency by raising the air temperature. The  $\text{SO}_2$  and  $\text{SO}_3$  included in the combustion gas (generated by the combustion of sulphur in fuel) causes the corrosion of the heat exchange element of APH in a low temperature range. Therefore, the temperature of the flue gas in APH must be kept within the proper range. For this purpose, a steam air heater (SAH) is equipped before APH to preheat the air to the adequate temperature (about  $80^\circ\text{C}$ ). SAH consists of heating tubes located in the air duct and heat exchange is carried out between the steam flow of tubes inside and the air flow of tubes outside. A fall of the temperature of the flue gas below the dew point results in condensation of water vapour and formation of sulphuric acid ( $\text{H}_2\text{SO}_4$ ), due to the pressure of oxides of sulphur. Formation of  $\text{H}_2\text{SO}_4$  damages the elements of the air heater.

After getting heat at APH to the temperature of about  $300^\circ\text{C}$ , the air goes through the air duct into a wind-box equipped around the fuel burner. The wind-box is an air buffer to distribute air equally to all burners. It is connected with air supply.



▲ Figure 5.3 Gas Recirculation System

The air supplied to the boiler furnace plays the role of combustion air so as to be fired completely. In this combustion process, the chemical energy contained in the fuel is converted to thermal energy. This thermal energy is transferred to the water in the boiler tubes predominantly with radiation to the water wall (water cooled wall) and mainly with convective heat transfer to the reheater and the superheater.

The cooled gas (about 150°C) is emitted from the stack to the atmosphere after being concentrated into one line. The stack itself has a function to give the exhaust gas a draft by virtue of the temperature difference between gas and atmosphere. In case a gas recirculation fan (GRF) is installed between the ECO and the APH, a part of the flue gas is recirculated into the boiler furnace. GRF is operated to control steam temperature, especially to prevent the steam from temperature drops during a low load operation. An increase in the amount of gas increases the convective heat transfer. Air and gas flows are shown as follows:

↑      ↓  
(GRF)

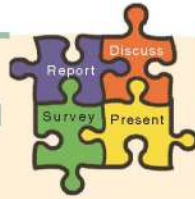
**▲ Figure 5.4 Actual Air and Gas Flow System**



Stop

4. What is a wind box?
5. Why is GRF operated?
6. What is the effect of  $\text{SO}_2$  and  $\text{SO}_3$  on heat exchangers?
7. What is the use of air preheater?

## Classroom



## Activities

1. Draw a flowchart diagram of a gas recirculation system. (P)
2. Explain to your friends why hot air from the surface move up and cold air moves down. (M)

### 5.4 SEALING AND COOLING AIR SYSTEMS

Sealing air is generally taken from two sources, as shown in Figure 5.5. One source is the outlet of FDF and the other source is the outlet of SAH.

The various uses of sealing air are as follows:

#### 5.4.1 Providing Combustion Air for Ignitors

Combustion air is boosted by an ignitor fan to maintain a higher draft of the ignitor wind box than that of the boiler furnace. This is done by differential pressure control using approximately 70 to 100 mm water column. This ensures cooling of ignitors and helps combustion.

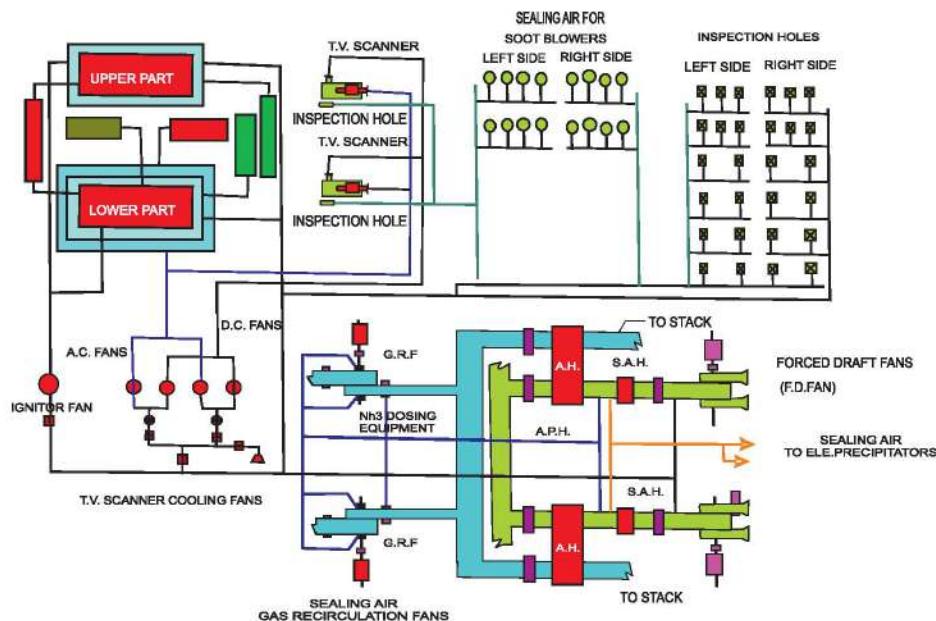
Ignitors' combustion air must be kept higher than the said draft at any point in time, especially in a low load operation because the draft at outlet of FDF decreases as the load decreases.

#### 5.4.2 Sealing the Gas around the Burners

Sealing air is supplied to seal the gas around the burners and to cool the inside of burner assemblies.

#### 5.4.3 Providing Air for Soot Blowers

Sealing air is supplied to prevent the leaked gas from penetrating parts between soot blowers and the furnace.



▲ Figure 5.5 Sealing and Cooling Air Flow Diagram

### Cooling air for T.V. monitors and flame scanners

The cooling air is boosted to obtain the required draft for cooling the T.V. monitors and flame scanners, especially the lens and electronic parts of the T.V. monitors. In this air system, D.C. T.V. scanner cooling fans are installed in parallel with A.C. T.V. scanner cooling fans to cope with emergency situations, like blackouts or power failures. The sealing air is used for GRF motors and damper sealing, electrostatic precipitators and NH<sub>3</sub> dosing equipment.



#### Check Your Progress

8. What is the use of sealing air in ignitors?
9. What are the sources of sealing air?
10. What is the use of sealing air in burners?

### Classroom



### Activities

1. Draw a chart containing two columns. On one side, list some equipment as parts in which sealing air is used and on the other side, describe the use of sealing air in the respective parts. (P)
2. Initiate a group discussion on the features of sealing air and put down your points highlighting its advantages. (M)

## 5.5 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ Air and flue gas system is used in a thermal power plant to ensure the required air supply for the combustion of fuel in the boiler furnace and to exhaust the resultant combusted flue gas into the atmosphere.
- ▶ The mechanical draft system is used to pressurize air at the proper point of flow.
- ▶ There are four types of draft systems.
- ▶ The balance draft system is the combined draft system of a FD (by a FDF) and an ID (by an ID fan).
- ▶ The FD system has only a FDF without an ID fan.
- ▶ The natural draft system does not have FDFs and ID fans.
- ▶ Sealing air is generally taken from two sources. One source is the outlet of the FDF and the other source is the outlet of steam air heater or SAH.
- ▶ Igniters' combustion air must be kept higher than the said draft at any situation, especially in a low-load operation because the draft at the outlet of FDF decreases as the load decreases.
- ▶ Sealing air for soot blowers is supplied to prevent gas leak from penetrating parts between the soot blowers and the furnace.

## 5.6 KEY TERMS

- ▶ **Stack:** A structure in which a number of chimneys are grouped together
- ▶ **Igniters:** Objects used to ignite or provide high heat to a substance for ignition (start of combustion)
- ▶ **Heat recovery:** The act of getting back or regaining heat
- ▶ **Sealing air:** Air used to close a passage

## 5.7 ANSWERS TO 'CHECK YOUR PROGRESS'

1. The different types of draft system are balanced draft system, forced draft (FD) system and natural draft system.
2. The natural draft system does not use a fan.
3. The natural draft system is a draft system which produces draft by the density difference between atmospheric air and hot gas. It uses a chimney for this purpose and does not use a fan.

4. A wind box is an air buffer to distribute air equally to all burners. It is connected with air supply.
5. GRF is operated to control steam temperature, especially to prevent the steam from temperature drops during low load operations.
6. The effect of  $\text{SO}_2$  and  $\text{SO}_3$  is that they cause corrosion on heat exchanger materials.
7. Air preheater is used to raise the plant efficiency by reducing the heat emitted out of the plant and to raise the combustion efficiency by raising the air temperature.
8. Sealing air is used as combustion air for ignitors, for soot blowing and to seal the gas around the burners.
9. Sources of sealing air are the outlets of forced draft fan (FDF) and steam air heater (SAH).
10. In burners, sealing air is used to seal the gas around the burners and to cool the inside of burner assemblies.

## 5.8 QUESTIONS AND EXERCISES

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### Short-Answer Questions

1. What is a duct?
2. How do draft losses occur?
3. What are the functions of draft systems?
4. What is the use of sealing air in soot blowers?
5. What is the function of a stack?

### Long-Answer Questions

1. Why must the temperature of flue gases in air preheaters be kept within a proper range?
2. Describe why air is boosted by ignitor fans.
3. Why must ignitors' combustion air be kept higher than the said draft at any situation?
4. Explain the characteristics of a forced draft (FD) system.

# 6

## Power Plant Cycles - Circulating Water System

### STRUCTURE

- 6.0 Introduction
- 6.1 Learning Objectives
- 6.2 Circulating Water System
- 6.3 Cooling Towers
- 6.4 Summary
- 6.5 Key Terms
- 6.6 Answers to 'Check Your Progress'
- 6.7 Questions and Exercises



## 6.0 INTRODUCTION

In this lesson, we will describe how water is used for cooling the steam in a condenser. This is known as circulating water system.

Since a large amount of water is required to remove the heat from the steam in the condenser, a sea or river is utilized as the source of water. However, where power stations are located in an inland district and sufficient quantity of water is not available, a recirculation system is adopted for cooling water with water cooling equipment such as cooling towers or cooling ponds.

The various requirements for cooling water in the circulating water system include low temperature, sufficient quantity of water and water free of solids such as dust, sand, mud or substances which may cause corrosion and erosion of the cooling tubes. These requirements can be met by adopting various counter measures and treatments, which will be discussed in this lesson in detail.

## 6.1 LEARNING OBJECTIVES

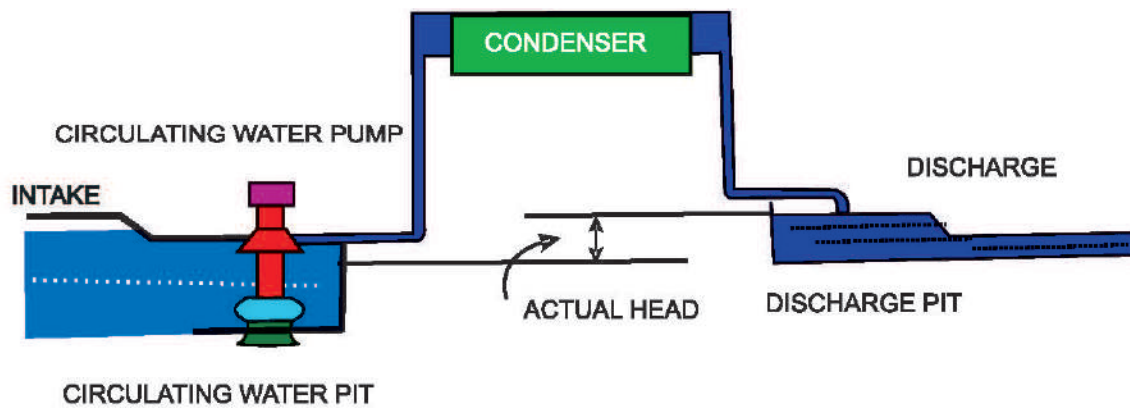
After going through this lesson, the trainee should be able to:

- ▶ Learn about circulating water system
- ▶ Understand the working of cooling towers

## 6.2 CIRCULATING WATER SYSTEM

The circulating water system supplies cooling water to the turbine condenser and thus acts as a medium through which heat is rejected from the steam cycle and released into the environment. The system consists of the following:

- ▶ Intake
- ▶ Intake culvert
- ▶ Intake pit
- ▶ Screen
- ▶ Circulating water pump
- ▶ Condenser
- ▶ Discharge culvert
- ▶ Discharge



▲ Figure 6.1 Circulating Water Flow

As shown in Figure 6.1, the circulating water flows from intake, passes through intake pump pit, circulating water pump, condenser and finally to the discharge pit. Figure 6.2 shows a typical circulating water system in which seawater or river water is utilized as cooling water (circulating water).

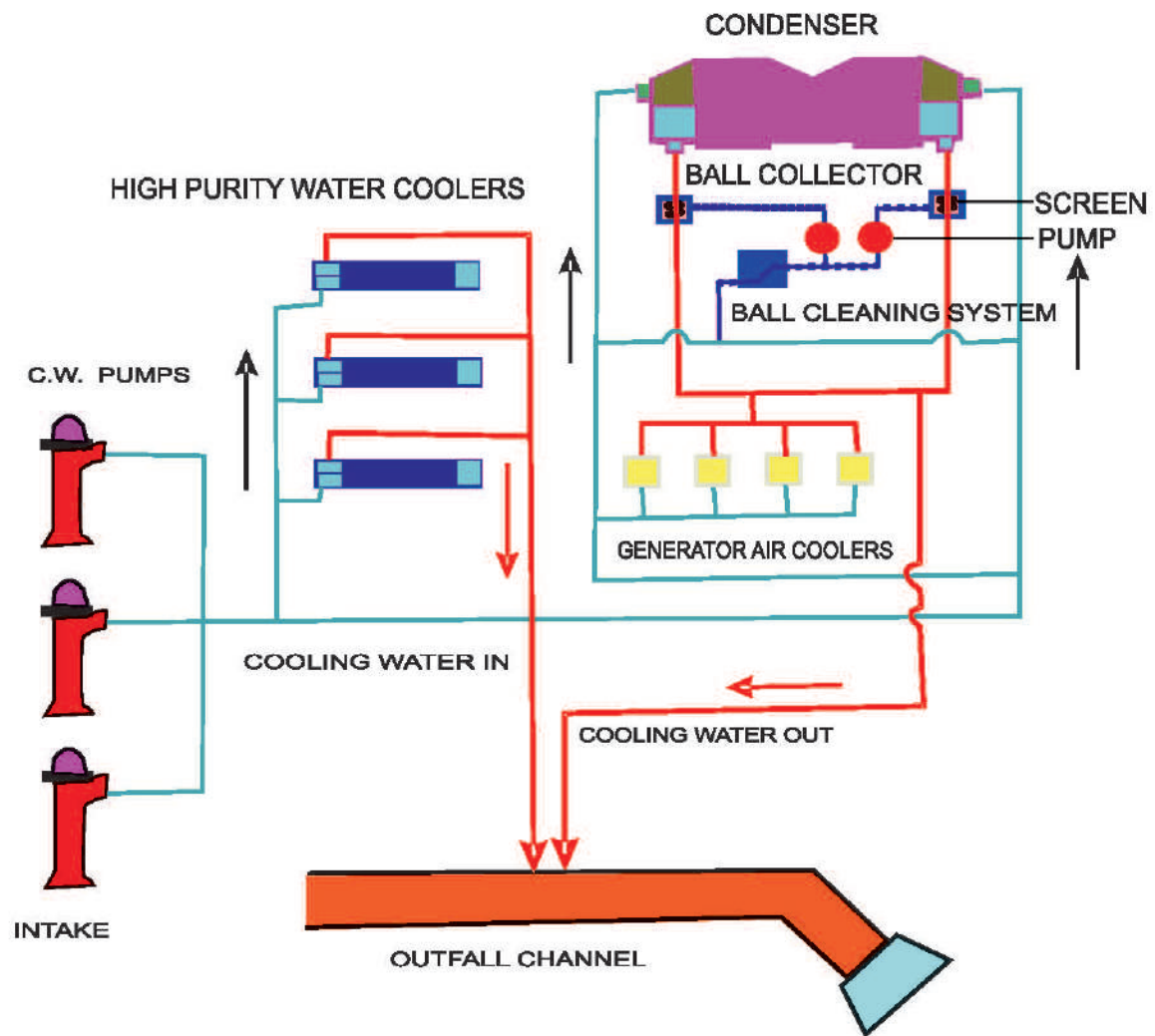
As shown in Figure 6.2, the sea or river water taken from the intake is led to the intake pump pit through culverts or buried pipings and pooled there. Various types of screens are used to keep the water free from foreign matter. Circulating water pumps (CWP) are installed to cover the pressure loss at the pipings condenser and the static head between the intake and the discharge culverts.

Usually, vertical mixed flow type pumps are adopted as CWPs and they are fitted above the intake pump pit with their suctions immersed in water. Usually two CWP units are equipped. The water pressurized by the CWP is led to the condenser and distributed into the cooling water tube. It absorbs heat from the exhaust steam of the turbine.

After the heat exchange in the condenser, the water is regathered in the water chamber on the opposite side of the condenser and is led to the discharge through the discharge culvert, from where it is finally discharged to the sea or the river. The discharge should be made at a distance enough from the intake so that the warm water may not recirculate in the system.

Sea or river water contains various impurities (suspended and dissolved). These impurities get deposited over the condenser tubes and result in the reduction of heat transfer. To clean the tubes on the line, the ball cleaning system is adopted. Sponge balls with a slightly larger diameter than that of the tube are injected at the inlet. While passing, they clean the tubes and are eventually collected at the exit of the condenser and are resent to the inlet by the pump.

Although the circulating water system is relatively simple, enough consideration should be given to achieve a proper (enough but not excessive) heat exchange. Moreover, because the equipment in this line is exposed to seawater which is highly corrosive, adequate attention must be paid to prevent corrosion and scale formation.



▲ Figure 6.2 Circulating Water System

**Stop**

### Check Your Progress

1. What is the use of a cooling water pump?
2. Name the elements of a cooling water system.
3. What is the disadvantage of exposing the equipment of a cooling water system to seawater?

## Classroom



## Activities

1. With the help of a diagram, identify the different equipment used in a circulating water system. (P)
2. Try to locate a nearby thermal power plant and observe whether the power plant is located near a sea or river. If yes, discuss why. (P)
3. Visit the SWCC power plant and find out the type of tube cleaning process that is in practice. Prepare a report on the practice being used and present it to your class. (M)



### Case Study - I

#### Making a Circulating Water System Equipment Work

##### Scenario

A thermal power plant was facing the problem of failure of the cooling water system equipment. The cost of the equipment was high and its failure was leading to the failure of the cooling system in the plant. This sometimes led to complete breakdown.

A technical committee was set up to find the solution to this problem. After research, the following reasons for failure were found:

- Corrosion of the cooling water system equipment
- Scale formation over the equipment

It suggested that the problems were rising due to the continuous exposure of the equipment to seawater, as seawater cooling system was being employed in these power plants.

The preventive measures suggested by the technical committee to overcome this problem were as follows:

- Seawater should be filtered and screened before supplying to the cooling water system. This will prevent the scale formation due to the presence of salt in water.
- Corrosion-free alloys and equipment should be used.

1. What was the problem faced by the thermal power plant? (P)
2. What were the reasons for that problem? (P)
3. Suggest some measures to solve the problem other than those given by the committee. (M)

## 6.3 COOLING TOWERS

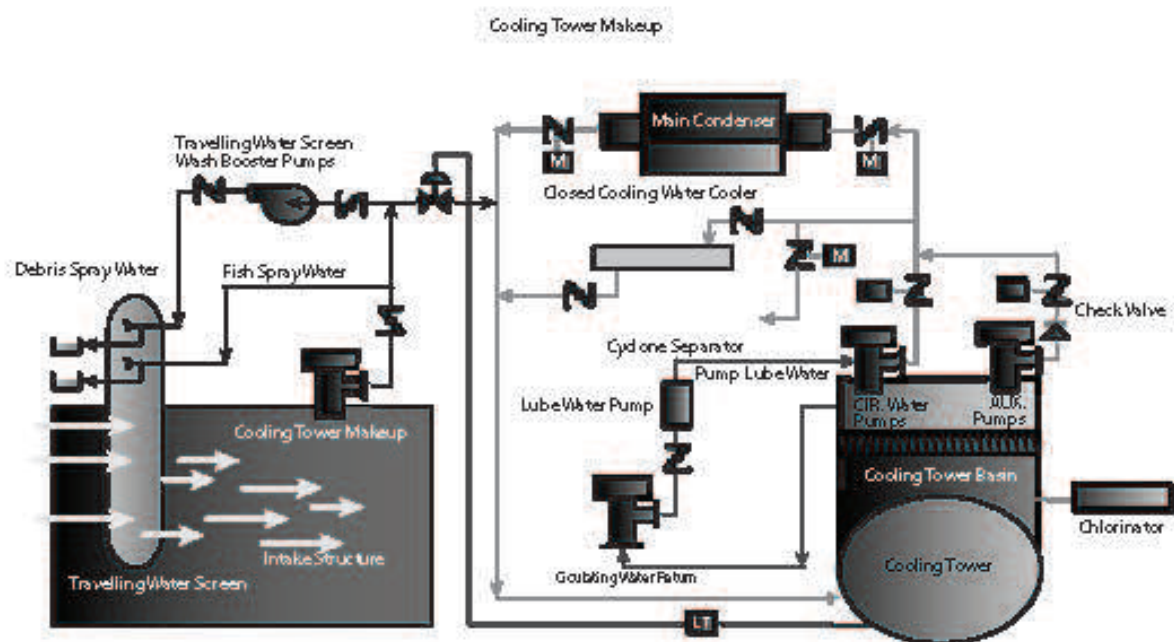
When an ample supply of water from a natural source is not obtainable, a cooling tower is used to cool the circulating water. The cooling tower cools the warm water discharged from the condenser and feeds the cooled water back to the condenser. This reduces the demand of cooling water in the power plant.

In a cooling tower, water is cooled by exposing large amounts of water to the air when circulating water is sprayed down in the cooling tower. The cooling of water takes place in two ways. The first process is that of sensible cooling in which the cold air takes away the heat of the hot water. The second process is that of evaporation. In this, if the relative humidity of air is less than 100%, some amount of water is evaporated by taking the heat from the water drops, thereby, cooling the drops. Generally, in the wet towers, 80% of the total cooling effect is achieved by evaporative cooling and the rest is due to sensible cooling.

The most commonly used cooling towers are the wet and dry types. Figure 6.3 shows the various parts of a cooling tower while Figure 6.4 shows the working of a cooling tower.

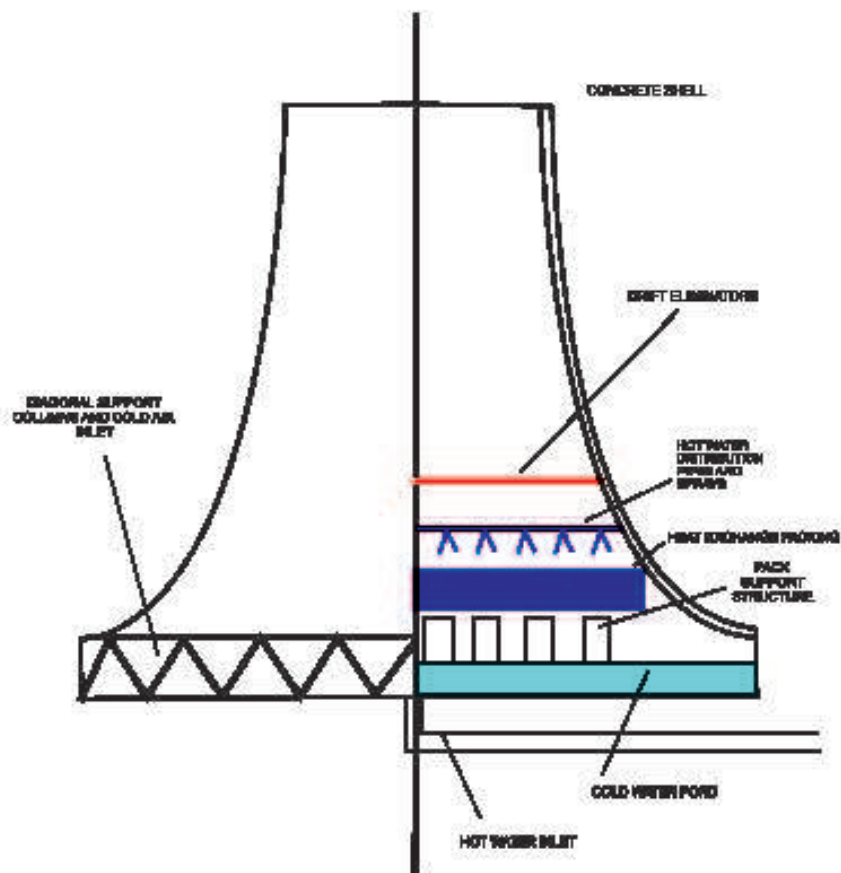


▲ Figure 6.3 Parts of an Induced Cooling Tower

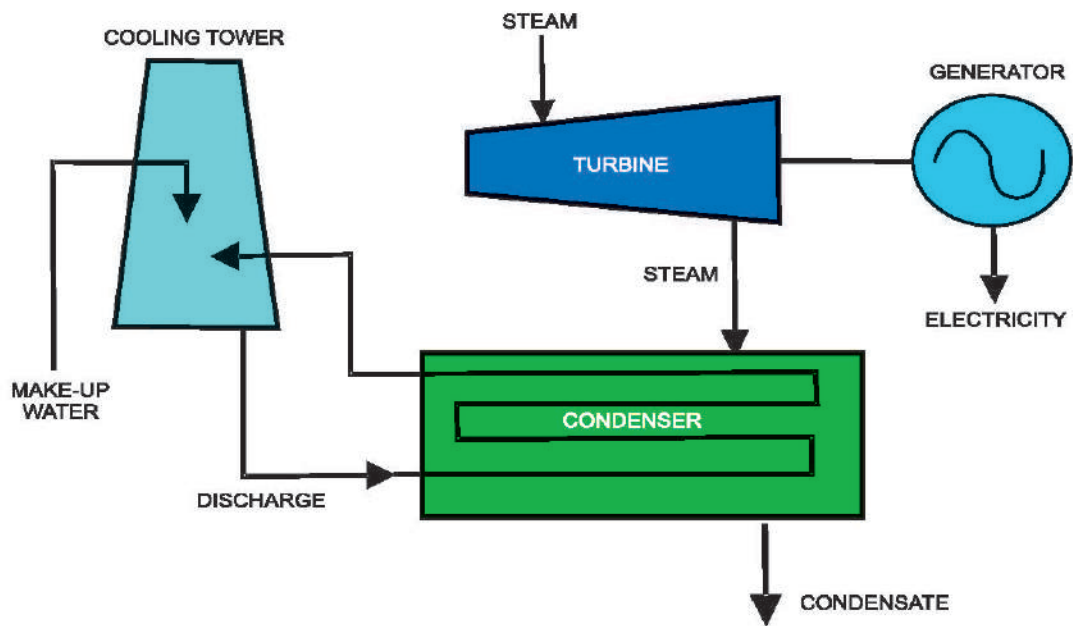


▲ Figure 6.4 Working of a Cooling Tower

Figure 6.5 shows a natural cooling tower, figure 6.6 shows a typical closed cycle cooling system and figure 6.7 shows a forced cooling tower.



▲ Figure 6.5 Parts of a Natural Draft Cooling Tower



▲ Figure 6.6 Typical Closed Cycle Cooling System



▲ Figure 6.7 Forced Cooling Tower

**Stop**

### Check Your Progress

4. How is cooling of water achieved?
5. What are the different types of cooling towers?
6. Why are cooling towers used in thermal power plants?



1. Using a diagram, explain the working of a cooling tower. (P)
2. Compare and contrast a circulating water cooling system and cooling tower cooling system. (M)



## Case Study - II

### Alternative to Cooling Water System

#### Scenario

The government of a nation decided to set up a thermal power plant in the country. While evaluating the options, the first problem which cropped up was that there was no river or sea near which the plant could be placed. This was necessary since power plants need river or seawater for the proper functioning of their circulating water system and condensing system.

Unable to find a solution to this problem, the government was on the verge of rejecting the proposal, when some research scholars came up with a new design which involved the use of cooling towers instead of a circulating or cooling water system. These cooling towers would use a recirculating water system in which the warm water discharged from the steam exhaust would be cooled and again recollected into the condenser.

As the new system promised to significantly reduce the demand for cooling water, the government approved the design.

1. What was the problem that cropped up while planning to set up the power plant? (P)
2. How do you think the use of a cooling tower instead of a cooling or circulating water system in the plant could solve the problem? (M)

## 6.4 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ The circulating water system in a thermal power plant is used to supply cooling water to the turbine condensers.
- ▶ The circulating water system in a thermal power plant acts as a medium through which heat is rejected from the steam cycle to the environment.
- ▶ A circulating or cooling water system is generally used at locations where there is no scarcity of water.
- ▶ The circulating water system consists of circulating water pump, condenser, discharge, screen, etc.
- ▶ Cooling towers are used in thermal plants when they are situated in places where supply of water is inadequate.
- ▶ Cooling towers cool the warm water discharged from the condenser and feed it back into the condenser.

## 6.5 KEY TERMS

- ▶ **Condenser:** An equipment used to cool any substance (like steam)
- ▶ **Inland district:** Refers to a place where there is scarcity of water
- ▶ **Recirculation system:** A system in which the same material is circulated in a cycle

## 6.6 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Circulating water pumps are used to cover the pressure loss at the pipings and the condenser and the static head between the intake and the discharge culverts.
2. A circulating water system consists of the intake, intake culvert, intake kit, screen, circulating water pump, condenser, discharge culvert and discharge.
3. The disadvantage of exposing the equipment of a circulating water system to seawater is that salt in seawater causes severe corrosion of the equipment.
4. Cooling of water is achieved by exposing a large amount of water to the air when circulating water is sprayed down in the cooling tower.
5. Cooling towers are of two types: wet and dry.
6. Cooling towers cool the warm water discharged from the condenser and feed the cooled water back into the condenser. This reduces the cooling water demand in the power plant, thereby making it easy to use in a place where there is scarcity of water.

## 6.7 QUESTIONS AND EXERCISES

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### Short-Answer Questions

1. What is the need of a circulating water system in a power plant?
2. What is the use of screens in a circulating water system?
3. Which type of cooling system is used in a thermal power plant when sufficient quantity of water is not available?

### Long-Answer Questions

1. Explain why a discharge should be located at a sufficient distance from the intake in a cooling water system.
2. Discuss how a cooling tower helps in reducing the cooling water demand in power plants.
3. Describe the uses of water in thermal power plants.



# 7

## Auxiliary and Secondary Steam Systems

### STRUCTURE

#### 7.0 Introduction

#### 7.1 Learning Objectives

#### 7.2 Auxiliary Steam System

#### 7.3 Secondary Steam Systems

##### 7.3.1 Purpose of the Secondary Steam System

##### 7.3.2 Process Description

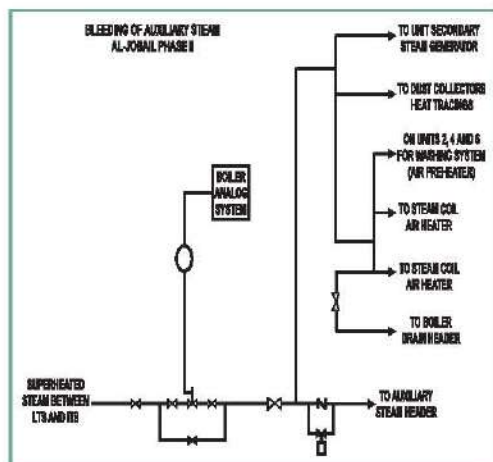
#### 7.4 Soot Blowing Steam System

#### 7.5 Summary

#### 7.6 Key Terms

#### 7.7 Answers to 'Check Your Progress'

#### 7.8 Questions and Exercises



## 7.0 INTRODUCTION

In a thermal power plant, there are many kinds of pipelines beside the main steam line to lead the steam to necessary machinery or equipment. These pipelines are collectively called auxiliary steam system.

In addition to these auxiliary steam systems, there are secondary steam systems in power plants, which have their own importance in the proper running of the power plant. In this lesson, you will study these auxiliary steam systems and secondary steam systems in detail.

Frequently, soot from the combustion gases in a power plant get deposited on water tubes. The effect of this phenomenon and the remedy for this problem have also been discussed in this lesson.

## 7.1 LEARNING OBJECTIVES

After going through this lesson, the trainee should be able to:

- ▶ Understand the working of auxiliary and secondary steam systems
- ▶ Learn about the soot blowing steam system

## 7.2 AUXILIARY STEAM SYSTEM

The function of the auxiliary steam circuits is to supply medium steam pressure of 18 bars to various auxiliary steam circuits.

In an auxiliary steam system, proper steam condition is required for each machinery or equipment. For example, a BFP requires high-pressure steam, but a kind of heater requires just the heat of steam. Therefore, auxiliary steam system has several pipings of different steam conditions.

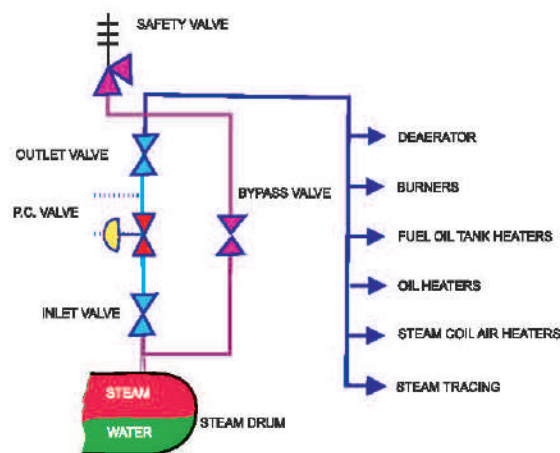
In some cases, the outlet steam of a boiler is directly used to obtain necessary steam condition. In other cases, steam condition is changed by the reducing valve or steam converter. On the other hand, the steam of low temperature reheater line or the steam extracted intermittently from the turbine is also used as auxiliary steam.

The auxiliary steam system includes the interconnecting piping network from the boiler connecting header between the L.T.S. and I.T.S. to the station secondary steam generator, desalination plant ejectors, steam coil air heaters, dust collector heat tracing, unit secondary steam generator and secondary steam system (Figure 7.1).

### System description

1. The auxiliary steam exits the boiler and the steam pressure is reduced to 15–20 bar g.
2. Downstream of the pressure reducing station is a flow transmitter.
3. After the flow transmitter, the auxiliary steam line branches to the following (also refer to Figure 7.1):
  - (i) Auxiliary steam header
  - (ii) Steam coil air heaters
  - (iii) Air heater and dust collector water washing system

- (iv) Dust collector heat tracing
  - (v) Unit secondary steam generator
4. The connection to the auxiliary steam header is through the non-return valve. A motor operated non-return valve bypasses a check valve.
  5. The auxiliary steam supplies steam to:
    - (i) Desalination plant ejectors
    - (ii) Station secondary steam generator
  6. The flow of steam to the steam coil air heaters is controlled by temperature control valves.
  7. The condensate from the steam coil air heaters is collected in a condensate collection tank.
  8. The steam supplied to the tube side of the Unit Secondary Steam Generator (USSG) goes through a pressure control station that is controlled by the pressure on the shell side of the USSG.
  9. The condensate from the USSG is collected in a USSG condensate collection tank.
  10. Auxiliary steam is also used for atomisation of heavy oil. Atomisation by steam breaks the oil into fine particles and improves combustion efficiency.



▲ Figure 7.1 Auxiliary Steam System

## 7.3 SECONDARY STEAM SYSTEM

In addition to the auxiliary steam system, there is secondary steam system in a thermal power plant. The primary steam system serves the purpose of supplying steam to the turbines, whereas the secondary steam system serves to supply steam to other equipment, such as the feedwater heaters, at the required pressure and temperature.

### 7.3.1 Purpose of the Secondary Steam System

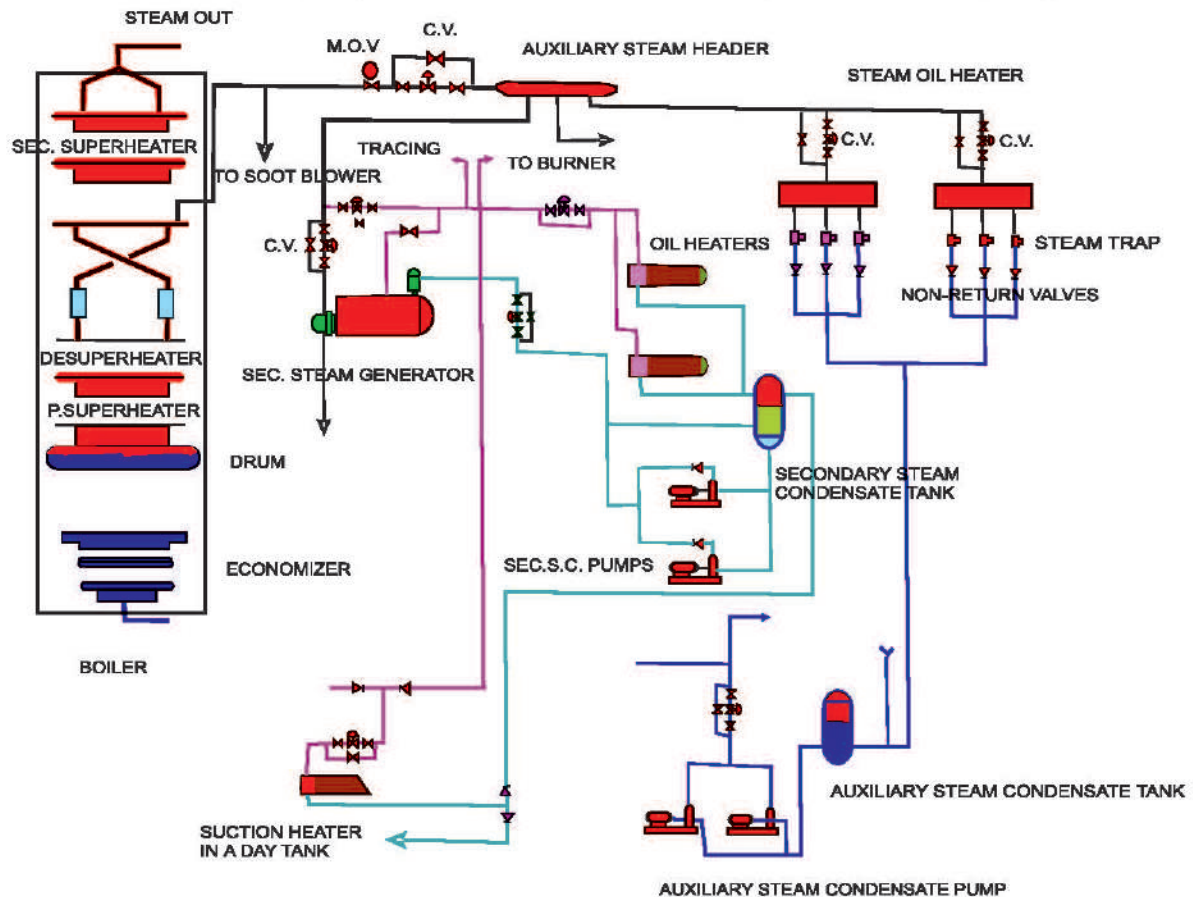
The secondary steam and condensate system also serves the purpose of heating the fuel oil in the storage tanks and along the way to the boiler burners. The secondary steam system is used to avoid contamination of the primary steam system. The tube side of the steam generator is at a higher pressure than that of the secondary circuit. Therefore, oil does not leak into the primary circuit.

### 7.3.2 Process Description

The secondary steam generator is installed to provide the closed loop fuel oil heating requirements for both steam generating units when firing bunker 'C' oil (heavy fuel oil).

The secondary steam generator is supplied on the tube side with steam from the auxiliary steam header and the trapped condensate is returned to the predetermined hot drains tank (Figure 7.2).

The steam generated in the shell of the vessel provides the heating medium (saturated steam) for each main fuel oil storage tank, heating bottom coil and suction heater coil and for each fuel oil heater, adjacent to the boilers when firing bunker 'C' oil (heavy oil).



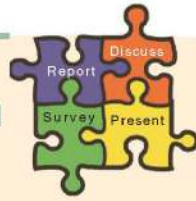
**▲ Figure 7.2** Auxiliary and Secondary Steam Systems



Stop

## Check Your Progress

1. What is the use of an auxiliary steam system?
2. Why does the auxiliary steam system have several pipings of different steam conditions?
3. Name the equipment to which an auxiliary steam system supplies steam.
4. Which device is used to control the flow of steam to the steam coil air heater?

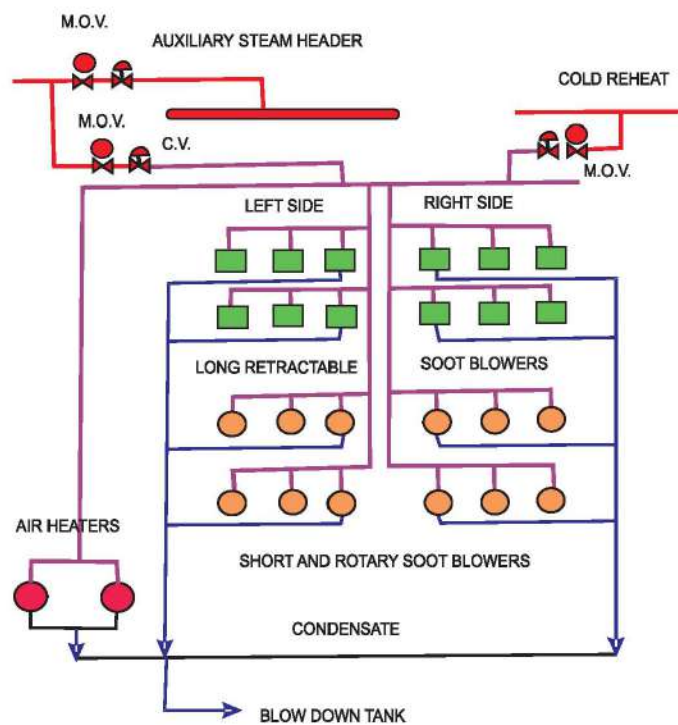


1. Explore the machines in your institute and identify where valves are used. (P)
2. Draw a sketch of an auxiliary steam system used in power plants. (P)
3. Make a comparative report of the secondary and the auxiliary steam systems. (M)

## 7.4 SOOT BLOWING STEAM SYSTEM

In a soot blowing system, soot blowing steam is led independently from the auxiliary steam header to each soot blower in order to avoid pressure drop effect on the other auxiliaries (refer to Figure 7.3). This steam is led to all long retractable and rotary soot blowers and soot blowers fitted onto the air preheater.

As the blowing steam must be free from condensate, each soot blower has a device for blowing down the drain and the drain is led to blow down the tank.



▲ Figure 7.3 Soot Blowing System

Stop

### Check Your Progress

5. Where is a soot blower fitted?
6. Where in an air preheater is the long retractable soot blower fitted?
7. What is the effect of soot blowing?



1. Draw a diagram of the soot blowing system. (P)
2. Describe the equipment of a thermal power plant where soot blowing is necessary. (M)



## Case Study - I

### Problem of Soot Deposition

#### Scenario

A power plant was facing a regular problem of soot deposition on the boiler tubes. The plant produced 698 KW of energy and used heavy fuel oil. The soot was the product of combustion and arose due to improper combustion of material.

Some of the effects of the soot were as follows:

The soot got deposited on the heating surface of the boiler and acted as a heat insulator. Due to this problem, less heat was transferred to the water used to raise steam and more heat was wasted, which went up the chimney leading to higher fuel consumption.

In order to remove the soot, the company installed a water cannon (Facos 2003) for soot blowing. As a result, the water canon blew out the soot with the flue gases.

Advantages of using this system were as follows:

- ▶ Reduction in outage time
- ▶ Significant energy saving upto 2%
- ▶ Reduction of tube erosion

1. What was the problem faced by plant? (P)
2. Name the supply system used in the plant. (P)
3. What were the advantages of using the supply system? Suggest some other methods to overcome the problem of soot deposition. (M)

## 7.5 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ Auxiliary steam systems are pipelines, which lead steam to necessary equipment at the required steam conditions.
- ▶ A secondary steam system serves the purpose of fuel oil heating in the storage tanks and along its way to boiler burners.
- ▶ Soot blowing systems serve the purpose of removing soot from the boiler tube walls.

## 7.6 KEY TERMS

- ▶ **Desalination plant:** The plant used for removing salts from seawater
- ▶ **Air heater:** A heater used to heat the combustion air by flue gases
- ▶ **Boiler feedwater pump (BFP):** A pump used to pump feedwater to a boiler
- ▶ **Auxiliary steam:** The steam extracted from a boiler or a turbine intermittently

## 7.7 ANSWERS TO 'CHECK YOUR PROGRESS'

1. An auxiliary steam system is used to lead steam to necessary machinery or equipment in a thermal power plant.
2. In the auxiliary steam system, proper steam conditioning is necessary for each machinery or equipment. While, a boiler feedwater pump (BFP) requires high pressure steam, a heater requires only the heat of the steam. Therefore, the auxiliary steam system has several pipings of different steam conditions.
3. An auxiliary steam system supplies steam to desalination plant ejectors and station secondary steam generators.
4. The flow of steam to the steam coil air heater is controlled by temperature control valves.
5. Rotary soot blowers are fitted onto air preheaters.
6. The long retractable soot blower is used for cleaning superheaters
7. The effect of soot blowing is that it removes the soot deposited on the boiler flue passes, and thus increases the heat transfer rate and ultimately the efficiency of the system.

## 7.8 QUESTIONS AND EXERCISES

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### Short-Answer Questions

1. What is an auxiliary steam system?
2. What is the function of the steam generated in the shell of a vessel?
3. Why is the secondary steam generator used?
4. Why does the soot blower have a blowing down drain?

### Long-Answer Questions

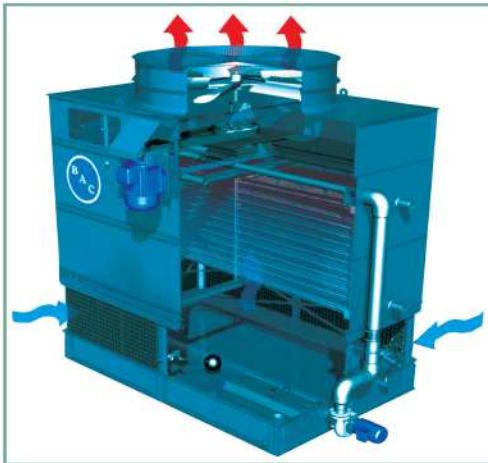
1. Describe the working of the auxiliary steam system.
2. What is the purpose of a secondary steam system?
3. How can oil leakage to primary circuit be avoided?

# 8

## Power Plant Cycles - Closed (Bearing) Cooling Water System

### STRUCTURE

- 8.0 Introduction
- 8.1 Learning Objective
- 8.2 Closed Cooling Water System
- 8.3 Summary
- 8.4 Key Terms
- 8.5 Answers to 'Check Your Progress'
- 8.6 Questions and Exercises



## 8.0 INTRODUCTION

In thermal power plants, cooling water systems are generally divided into closed cycle cooling water system and once-through seawater cooling system.

Fresh water is used as the cooling medium in the former system and the equipment, which is preferable to be isolated from direct contact to the water including impurities such as seawater, are cooled by this system.

Seawater is used as the cooling medium for the purpose of cooling the medium of closed cycle. In this unit, you will learn about the closed cooling water system in detail.

## 8.1 LEARNING OBJECTIVE

After going through this lesson, the trainee should be able to:

- Understand the working of the closed cooling water system

## 8.2 CLOSED COOLING WATER SYSTEM

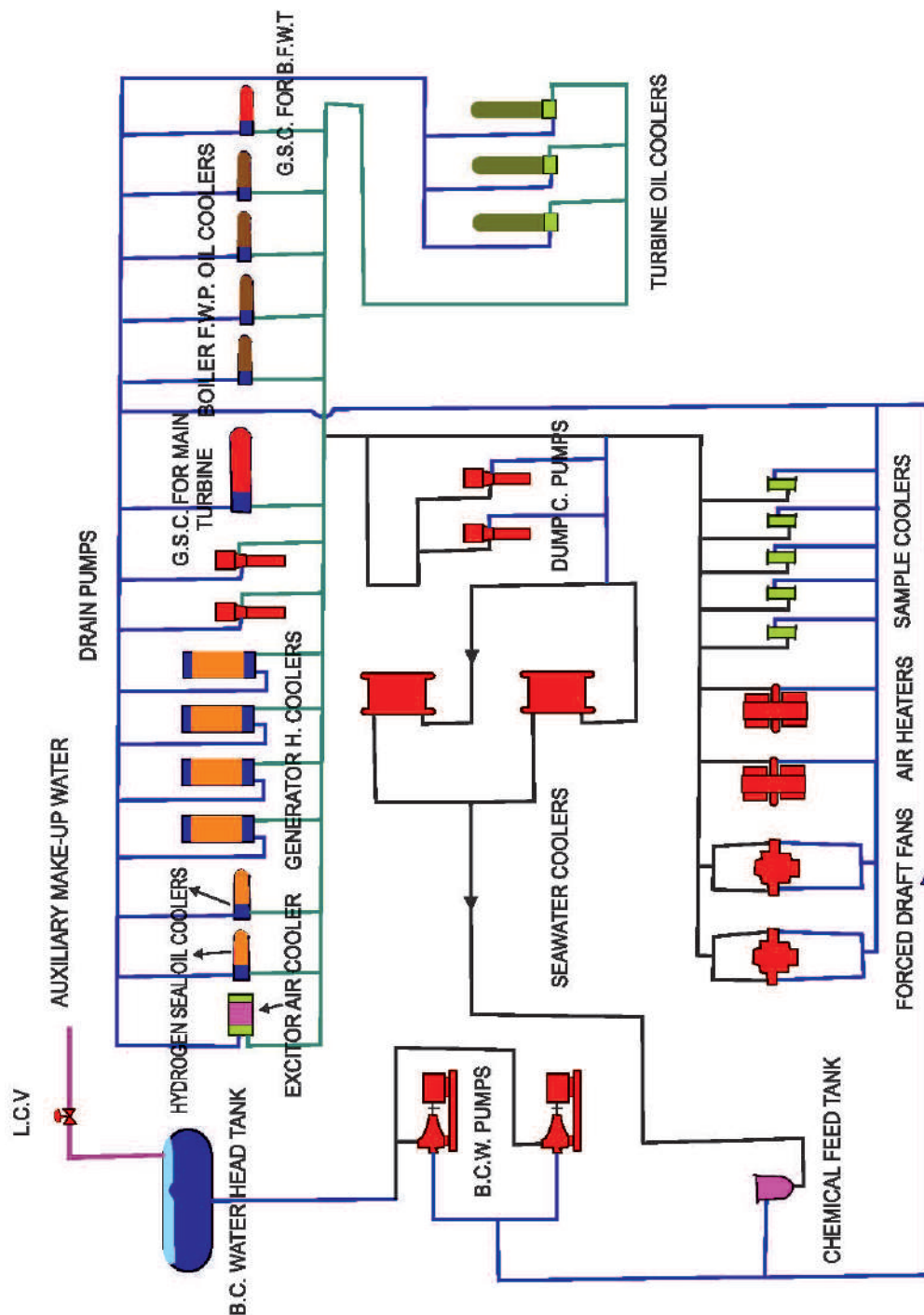
Cooling water is pumped from the cooling water head tank or return pipe after passing through the cooling water heat exchanger. The cooling water itself is cooled down by seawater in the cooling water heat exchanger.

Cooling water is fed to excitor air coolers, hydrogen seal oil coolers, generator hydrogen coolers, gland steam condensers, lubricating oil coolers and sample coolers, bearing cooling of FDFs, air heaters, condensate pumps, drain pumps and boiler feedwater pumps, etc.

After cooling these, the cooling water is led to the suction of the cooling water pump. The water level of the cooling water head tank is automatically controlled by filling make-up water.

Seawater is led to the heat exchanger and discharged to the outfall channel. Such a cooling system is also known as once-through cooling system since the same seawater never returns back into the system. In addition, the working medium of chillers is also cooled by this seawater.

The closed cycle cooling water flow diagram is shown in Figure 8.1.



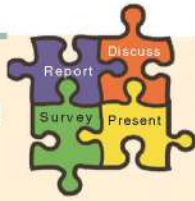
▲ Figure 8.1 Closed (Bearing) Cooling Water System

**Stop**

### Check Your Progress

1. What are the two types of cooling water systems?
2. Name the cooling medium used in a closed cooling water system.
3. How is the water level of the cooling water tank controlled?

## Classroom



## Activities

1. Find practical examples of instruments and machines in which water is used as a cooling agent. (P)
2. Draw a sketch of a closed cooling water system. (P)
3. Compare the closed cycle cooling water system and the seawater cooling system and prepare a presentation of the same. (M)
4. Make an onsite tour of your power plant and analyse the circulating water system in it. (D)

### 8.3 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ The bearing or closed cooling water system in a thermal power plant is used to absorb the waste heat generated by various equipment in the power plant.
- ▶ If a cooling water system is not established in a thermal power plant, it will lead to overheating and subsequent damage of the equipment.
- ▶ Fresh water is used as the cooling medium in closed cycle water systems.
- ▶ The seawater cooling system is used to cool a number of heat exchangers and working medium of chillers.

### 8.4 KEY TERMS

- ▶ **Fresh water:** The water that is free from any kind of salt and impurities
- ▶ **Heat exchanger:** The instrument that is used to supply or absorb heat from a medium
- ▶ **Draft fan:** A fan that is used in power plants for circulation of flue gases

### 8.5 ANSWERS TO 'CHECK YOUR PROGRESS'

1. The two types of closed water cooling systems are as follows:
  - ▶ Closed cooling water system
  - ▶ Seawater cooling system

2. Fresh water is used in a closed water cooling system.
3. The water level of a cooling water head tank is automatically controlled by filling make-up water.

## **8.6 QUESTIONS AND EXERCISES**

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### **Short-Answer Question**

1. What types of equipment are preferred to be cooled by fresh water?

### **Long-Answer Question**

1. Describe the working of a closed cooling water system.



# 9

## Fuel Oil and Gas Systems

### STRUCTURE

- 9.0 Introduction
- 9.1 Learning Objectives
- 9.2 Fuel Oil System
- 9.3 Fuel Gas Firing System
- 9.4 Summary
- 9.5 Key Terms
- 9.6 Answers to 'Check Your Progress'
- 9.7 Questions and Exercises



## 9.0 INTRODUCTION

In a thermal power plant, the supply system consists of fuel oil tank, fuel oil pump, fuel oil heating, and filtering apparatus and combustion control apparatus. The fuel oil tank is filled with fuel supplied from the storage. Oil transfer equipment provides suction of oil pump and returns connection from burners.

The pressure and temperature of the fuel discharged from the fuel pump through the oil heater is controlled automatically. This maintains an optimum condition of combustion required for each boiler load. In this lesson, fuel oil and gas supply systems to the boiler have been described.

## 9.1 LEARNING OBJECTIVES

After going through this lesson, the trainee should be able to:

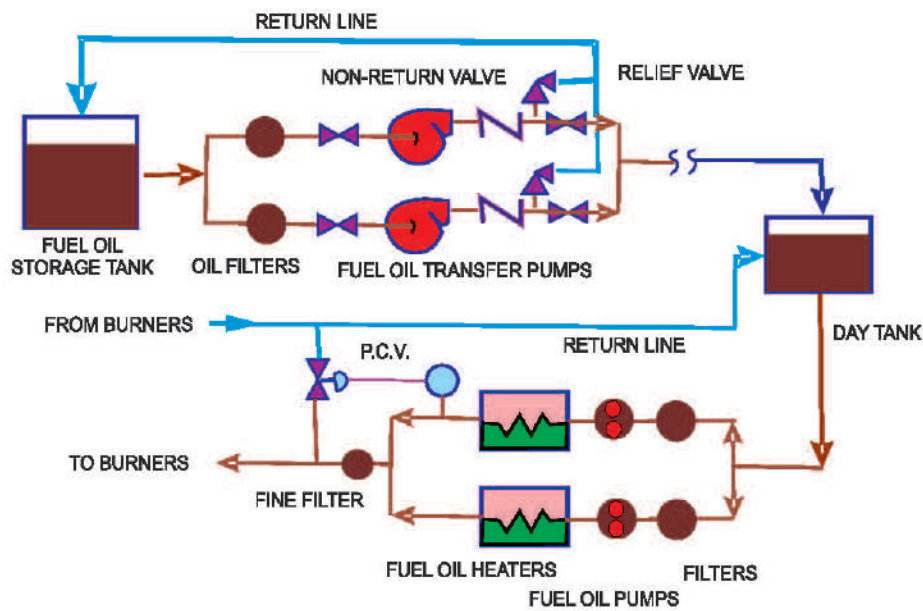
- ▶ Discuss the heavy fuel oil system
- ▶ Describe the fuel gas firing system

## 9.2 FUEL OIL SYSTEM

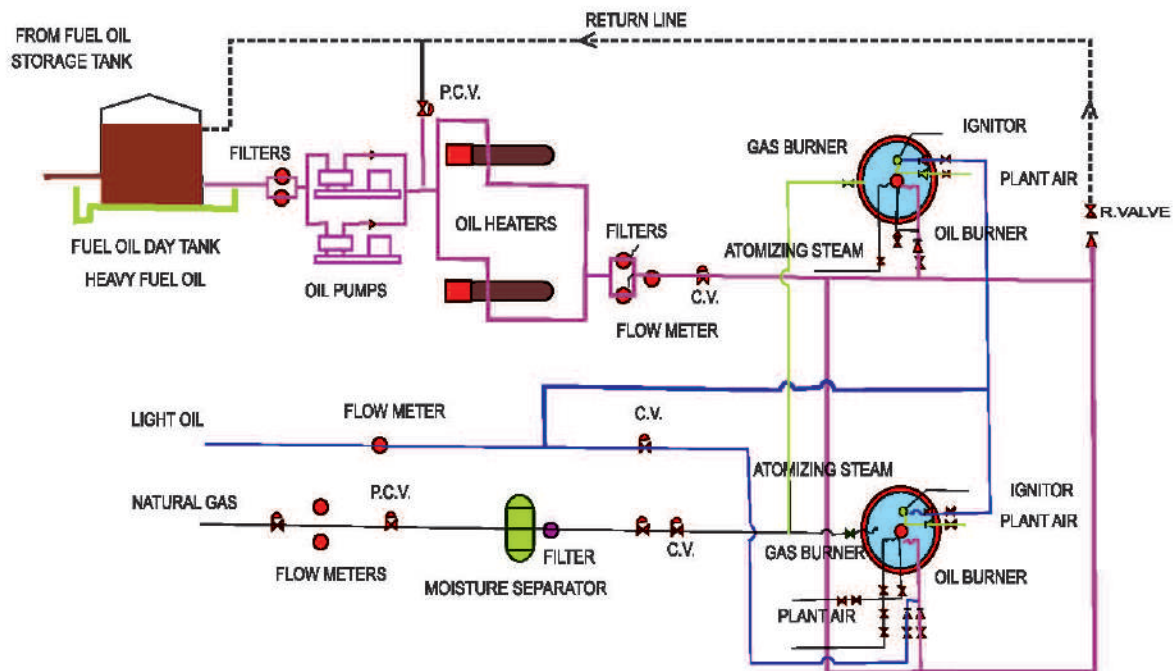
The main components of the fuel oil system are as follows:

- ▶ **Suction heater:** It is provided at the suction port on the fuel oil tank to ensure fluidity of heavy oil.
- ▶ **Fuel oil pump:** It is normally a constant volume type pump such as the screw pump.
- ▶ **Relief valve:** It is provided on the discharge of the fuel oil pump to prevent excessively high pressure.
- ▶ **Pressure control valve:** It is also provided on the line between pump and heater. Fuel oil released from valves collects in the fuel oil return pipe and returns back to the fuel oil tank.
- ▶ **Oil heater:** It controls fuel oil temperature to get adequate viscosity of fuel oil for good condition of spray and combustion.
- ▶ **Fuel control apparatus:** In a combustion control system, it is provided on the fuel supply line before the burners.

Flow diagrams of a fuel supply system and a fuel burning system have been shown in Figures 9.1 and 9.2, respectively.



▲ Figure 9.1 Heavy Fuel Oil Supply System

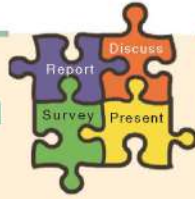


▲ Figure 9.2 Fuel Burning System

**Stop**

### Check Your Progress

1. Why is a suction heater provided at the suction port on a fuel oil tank?
2. What is the use of a relief valve?
3. What is the advantage of oil heaters?
4. Where is the pressure control valve located?



1. Name a few equipment or media in which fuel oil system is used. (P)
2. Draw a diagram of a fuel supply system. (P)



## Case Study - I

### Failure of a Power Plant

#### Scenario

A 1050-KW power plant stopped working. The electricity produced by this power plant was satisfying the demand of two of the biggest business towns. This disturbance in electricity production led to non-availability of electricity for three days in those towns. Service engineers were not able to identify the reason of failure of the plant. The company then planned to hire specialist engineers from abroad. The engineers took approximately twenty-four hours to find out the defect. They concluded that a small leakage was the defect. Owing to the leakage, the boiler was not getting sufficient amount of oil for proper combustion. The oil was leaking and was not reaching the desired destination. After this incident, which brought a loss of at least 60 million dinars to the company, the company took the following measures:

- ▶ Regular survey of fuel oil system and regular report submission were made mandatory.
  - ▶ Service engineers were given specific training about the fuel oil system.
1. What was the defect in the thermal power plant? (P)
  2. What were the measures suggested by the service engineer for the smooth functioning of the power plant? (M)

### 9.3 FUEL GAS FIRING SYSTEM

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The outline of boiler fuel gas firing system is shown in Figure 9.3.

The main components of a fuel gas system are as follows:

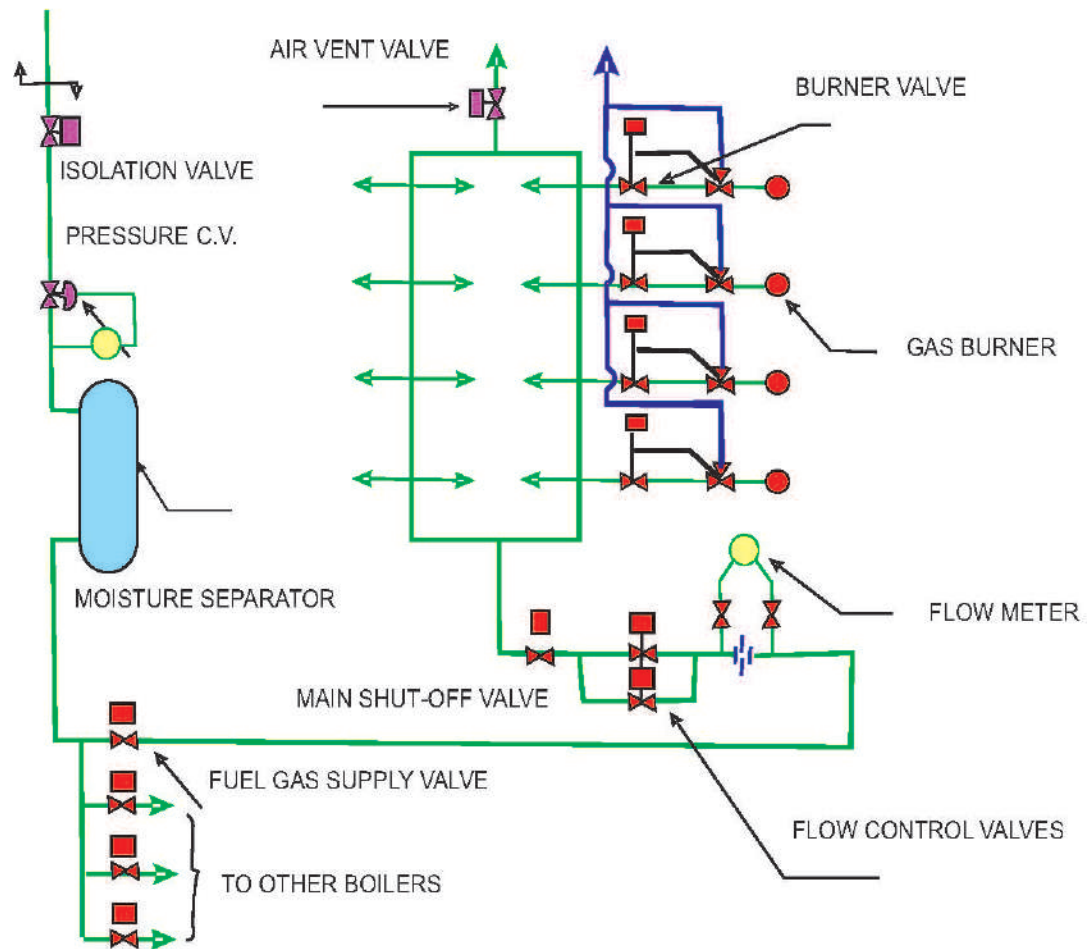
- ▶ Pressure reducing valves
- ▶ Moisture separator
- ▶ Relief valves
- ▶ Flow meter
- ▶ Flow control valve
- ▶ Shut-off valve
- ▶ Air vent valve
- ▶ Burner valves

The main features of the firing system in power plants are as follows:

- ▶ The pressure reducing valves and moisture separator are used in common for all boilers.
- ▶ The fuel gas is supplied to the plant from the gas refinery through a pipeline.
- ▶ The fuel gas pressure is reduced to about 7 bar through the pressure reducing valves. Then the gas is supplied to all the boilers through the moisture separator.
- ▶ The moisture separator is used to separate the drain, which is formed in the gas pipe during transfer and reduce gas pressure. The fuel gas, being separated in the common line, is supplied to the burner through the flow meter, flow control valve and shut off valve.
- ▶ The fuel gas flow to the boiler is controlled by the boiler automatic combustion control system to meet the boiler load.
- ▶ The fuel gas shut off valve is provided to cut off the gas supply to the boiler in case of emergency.
- ▶ The gas burner valve is the special ball valve with an integral vent valve. When it is opened, both the inlet and outlet sides of the valve are open and the integral vent valve at the middle is closed in order to prevent the gas from leaking to the furnace.
- ▶ The air vent valve at the common header is used to stabilize the gas burner pressure at the time of low condition of gas flow and to purge the gas supply line.
- ▶ N<sub>2</sub> gas lines are installed to purge the fuel gas lines for the following purposes:
  - To maintain the safety of the gas lines in case of a long boiler outage or a long outage for repairing pipeline
  - To replace air in the fuel gas lines with N<sub>2</sub> gas prior to admitting fuel gas

- $N_2$  gas lines are connected to the fuel gas supply line downstream from the fuel gas supply valve and shut off valve. This is done so that the fuel gas line can be purged with  $N_2$  gas when the unit is shut down for a long period or gas pipes are to be repaired

#### FUEL OIL SUPPLY

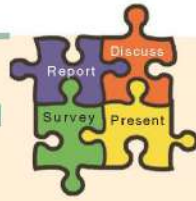


▲ Figure 9.3 Boiler Fuel Gas Firing System

**Stop**

#### Check Your Progress

5. What equipment does a fuel gas system consist of in a thermal power plant?
6. What is the use of the moisture separator?
7. Which is the valve used to cut off the gas supply to the boiler in case of an emergency?
8. State the use of an air vent valve at the common header.



1. Draw a sketch of a fuel gas firing system. (P)
2. List the parts of the boiler fuel gas firing system. (P)

## 9.4 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ A thermal power plant supply system consists of the fuel oil tank, the fuel oil pump, the fuel oil heating, and the filtering apparatus and combustion control apparatus.
- ▶ A fuel oil system is used in a boiler to provide necessary oil and fuel to the boiler at a required pressure and temperature.
- ▶ A fuel oil system consists of components such as suction heater, fuel oil pump, relief valve, pressure control valve, oil heater and fuel control apparatus.
- ▶ Main components of the fuel gas system are as follows:
  - Pressure reducing valves
  - Moisture separator
  - Receiving valves
  - Flow meter
  - Flow control valve
  - Shut off valve
  - Air vent valve
  - Burner valves
- ▶ Nitrogen gas lines are installed in a power plant to purge and maintain the safety of the gas lines.
- ▶ Firing system is the system in a power plant that causes sparks or fire during combustion of fuel gas.

## 9.5 KEY TERMS

- ▶ **Moisture separator:** An equipment used to separate drains in the gas pipe line
- ▶ **Suction heater:** An instrument which provides fluidity to heavy oil
- ▶ **Oil heater:** An instrument which controls fuel oil viscosity and temperature
- ▶ **Combustion system:** A system consisting of various equipment for the proper combustion of fuel
- ▶ **Oil transfer equipment:** The equipment that provides relief of oil pumps and returns connection from burners

## 9.6 ANSWERS TO 'CHECK YOUR PROGRESS'

1. A suction heater is provided at the suction port on a fuel oil tank for the fluidity of heavy oil.
2. A relief valve is used to prevent excessively high pressure in the fuel oil system.
3. The advantage of oil heaters is that they control fuel oil temperature to get adequate viscosity of fuel oil for good condition of spray and combustion.
4. The pressure control valve is located on the line between a pump and a heater.
5. A fuel gas system consists of the fuel gas reducing valve, fuel gas moisture separator, fuel gas receiving valve, flow meter, flow control valve, shut off valve, air vent valve, burner valves, etc.
6. The moisture separator is used to separate the drain, which is formed in the gas pipe during transfer and reducing gas pressure.
7. The fuel gas shut off valve is used to cut off the gas supply to the boiler in case of emergency.
8. The air vent valve at the common header is used to stabilize the gas burner pressure at the time of low condition of gas flow and to purge the gas supply line.

## 9.7 QUESTIONS AND EXERCISES

### Short-Answer Questions

1. What does a supply system consist of?
2. Why are screw and relief valves provided on a fuel oil pump?
3. What is the advantage of automatic control of pressure and temperature of fuel discharge from the fuel pump?

### Long-Answer Questions

1. Describe how fuel gas is supplied to boilers.
2. Explain how fuel gas flow to the boiler is controlled.
3. Explain why nitrogen gas lines are installed.
4. Discuss why nitrogen gas purge lines are connected to fuel gas supply.

# 10

## Compressed Air System

### STRUCTURE

#### 10.0 Introduction

#### 10.1 Learning Objectives

#### 10.2 Compressed Air System

##### 10.2.1 Instrument Air System

##### 10.2.2 House Service Air System

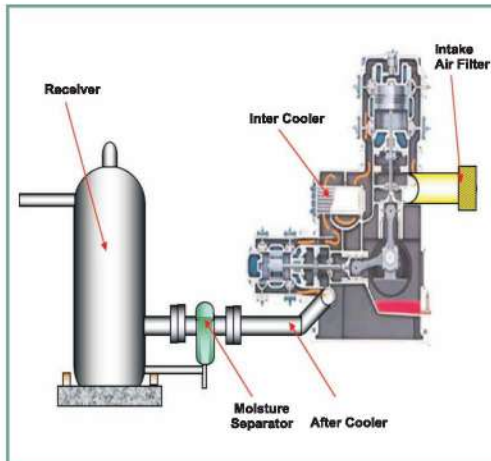
##### 10.2.3 Soot Blower System

#### 10.3 Summary

#### 10.4 Key Terms

#### 10.5 Answers to 'Check Your Progress'

#### 10.6 Questions and Exercises



## 10.0 INTRODUCTION

Thermal power plants use compressed air to store energy, which is generated at a certain time for use during another occasion. Compressed air is extensively used in power plants, manufacturing plants, and also for cleaning and drying. Moreover, a compressed air system can be used for instrument air system, house service air system and also for the soot blowing air system.

In this lesson, you will learn about the compressed air system that is used in thermal power plants.

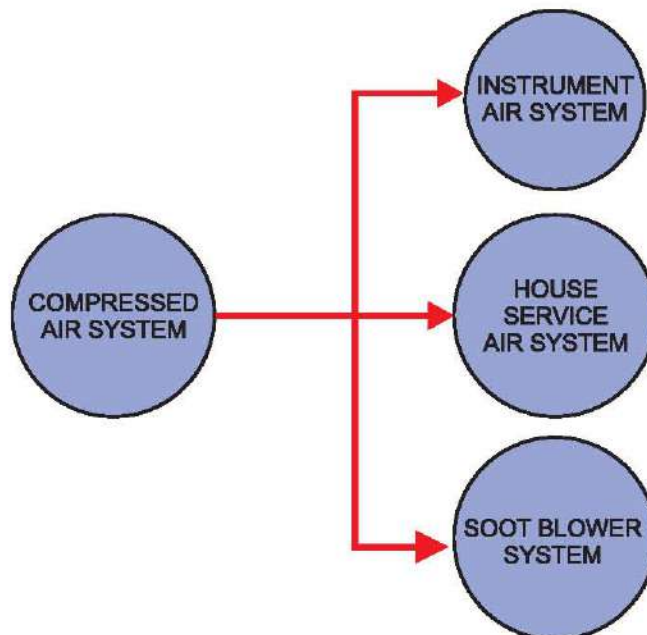
## 10.1 LEARNING OBJECTIVES

After going through this lesson, the trainee should be able to:

- ▶ Understand compressed air system
- ▶ Describe house service air system and instrument air system

## 10.2 COMPRESSED AIR SYSTEM

Generally, in a thermal power plant, compressed air is used for the instrumental air system, house service air system and, in some cases, for the soot blowing system (Figure 10.1). Service air is also used for atomization of high-speed diesel (HSD) oil. This oil is used to ignite the heavy fuel oil.



▲ Figure 10.1 Compressed Air System

### 10.2.1 Instrument Air System

Most of the instruments that are used in a power station work with the air pressure. Instrument air system is the air supplying and distributing system for these air-driven instruments.

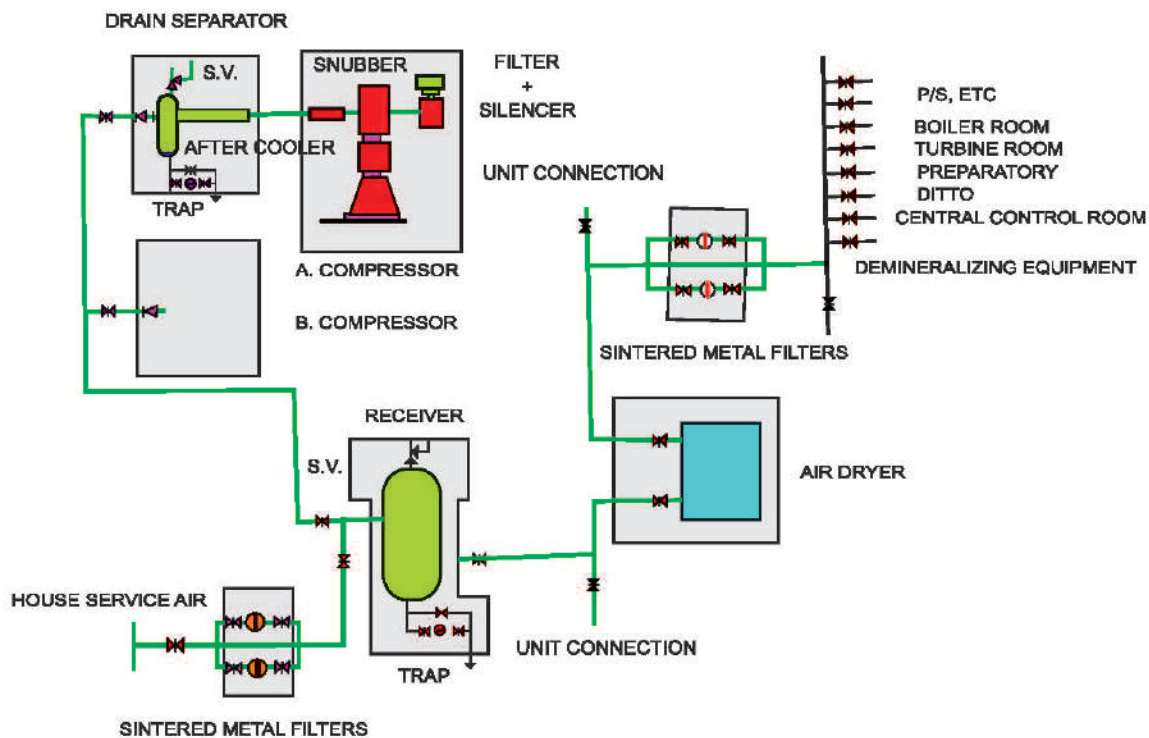
Figure 10.2 shows an air flow instrument, which shows the air flow from the atmosphere, through various instruments such as, compressors, after-coolers, air receivers, air dryers and air distribution headers. Instruments require clean and dry air. To satisfy this requirement, various other things have to be in place such as:

- ▶ Air cleaner at the inlet of compressor
- ▶ Oil-less compressor to prevent the oil fumes from being mixed
- ▶ Oil separator to remove the mingled oil in case of oil lubricated type compressor
- ▶ Air dryer to remove the humidity

The pressure of the instrument air is usually about 7 bar g at supply and is reduced to the required pressure for each instrument. The volume of the receiver is decided to be 1–2 times of the air consumption rate ( $\text{m}^3/\text{min}$ ) in order to prevent the air pressure from being reduced in case of the load change.

For the air dryer, a moisture absorbing method (dehumidifier) is usually utilized. The air dryer is generally composed of two columns in parallel in which silica gel is filled as the absorbing medium—one is in operation and the other is in regenerating process.

For an instrument air compressor, a single or double stage reciprocating compressor is usually adopted. However, recently in some cases, axial flow compressors are also being adopted in this application.



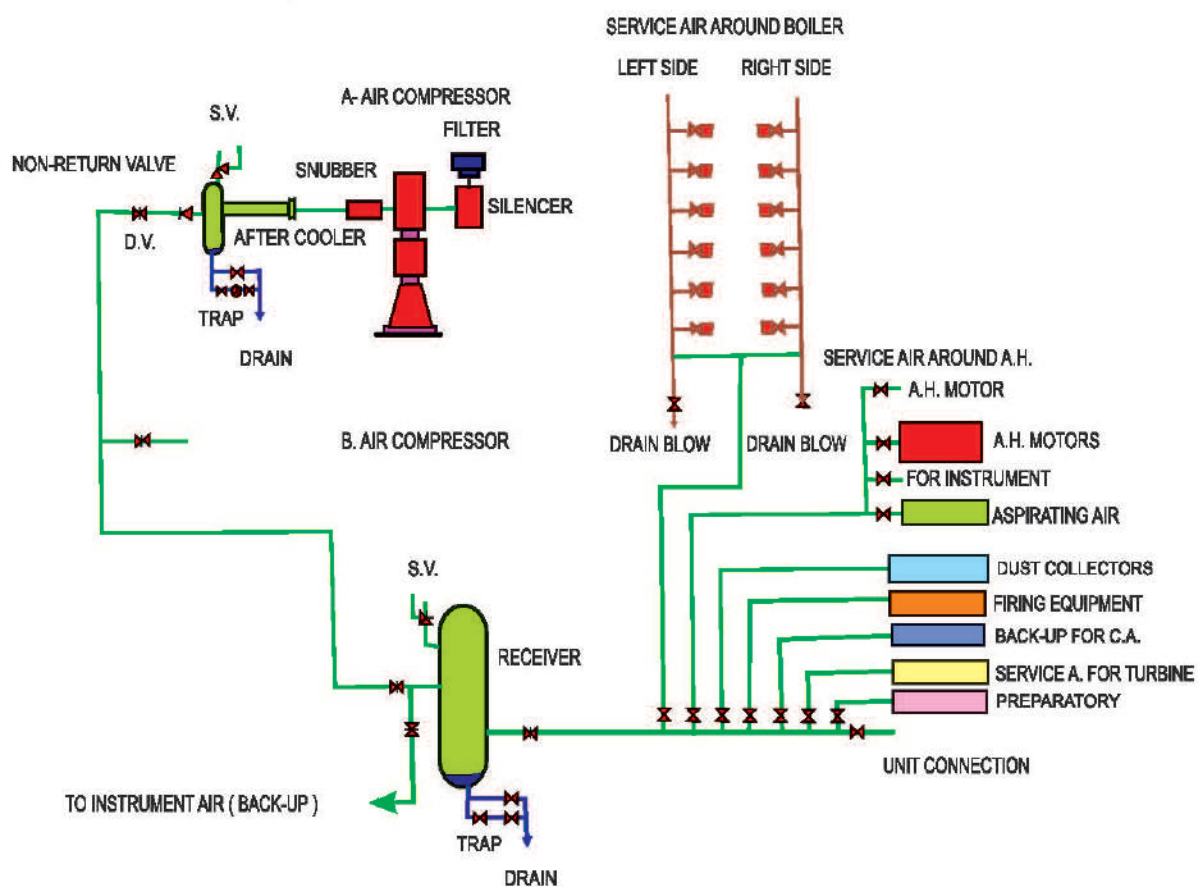
▲ Figure 10.2 Instrument Air System

## 10.2.2 House Service Air System

The house service air system is supplied to each equipment for the following uses (see Figure 10.3):

- ▶ For general use in the house
- ▶ For burner ignition
- ▶ For purging of pipings (washing)
- ▶ For aspiration of boiler accessories
- ▶ Various other uses

For the above uses, clean and dry air is not always required. Therefore, in this case, the air dryers are not fully utilized.



▲ Figure 10.3 House Service Air System

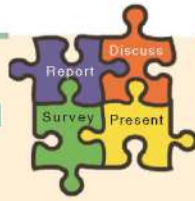
### 10.2.3 Soot Blower System

A soot blower system is a system of soot blowers, where each is capable of cleaning ash deposits from the walls of a furnace chamber. The action of this system is in direct response to the local heat transfer rate from the hot combustion products to the furnace walls. The soot blower system functions sensed by one or more heat flux meters mounted on the furnace wall in the general region surrounding the soot blowers.

**Stop**

#### Check Your Progress

1. List the uses of compressed air.
2. What is the use of the instrument air system?
3. What is an air flow instrument used for?
4. Give two uses of a house service air system.



1. Give some practical examples where compressed air is used. (P)
2. Compare the house service air system with the instrument air system. (M)
3. Invite a guest lecturer to speak on compressed air systems and their use in power plants. Make a list of questions that can be asked. (D)



## Case Study - I

### Compressed Air Power Plant

#### Scenario

An unpleasant incident occurred in a 1050-MW power plant. Government officers were on a tour of the plant regarding the proposed investment in the plant. Everything was going smoothly until a compressed air pipe blast off. The high pressure air led the attached sharp hose tool to blow off. The tool directly hit the forehead of a senior engineer resulting in serious injuries. The primary reason behind this accident was the weak coupling, which got loose due to the consistent supply of high-pressure compressed air, irregular maintenance and survey.

After this accident, the company took various preventive measures. Some of them were as follows:

- A training programme was introduced in which the destructive potential of compressed air was provided.
  - New methods and technologies were suggested for proper air supply.
  - Regular surveys of compressed air powered equipment were conducted to assess the integrity of the coupling, clamps and hoses.
1. How was the senior engineer injured? (P)
  2. What was the reason for the accident? (M)
  3. What preventive steps were taken after the accident? (D)

### 10.3 SUMMARY

The following bullet points will summarize this lesson for you:

- ▶ Compressed air is widely used in many fields. Some of the fields are as follows:
  - Power plants
  - Manufacturing plants
  - Cleaning
  - Drying
- ▶ A compressed air system can be used for instrument air system, house service air system and also for the soot blowing air system.
- ▶ An instrument air system is the main system for supplying and distributing air in many thermal power plant equipment.
- ▶ An air-flow instrument shows the air flow from the atmosphere, through various instruments. Some instruments are as follows:
  - Compressors
  - After-coolers
  - Air receivers
  - Air dryers
  - Air distribution headers
- ▶ A moisture-absorbing method (dehumidifier) is used for the air dryer.
- ▶ Multi stage compressors are usually adopted for an instrument air compressor.
- ▶ House service air is supplied to each equipment for the following purposes:
  - Aspiration of boiler accessories
  - Purging of pipings (washing)

## 10.4 KEY TERMS

- ▶ **Reciprocating compressor:** A compressor in which air is compressed to a high pressure by using a piston driven by a crankshaft
- ▶ **Soot blower system:** A system in which the soot deposited on the boiler walls is blown away by using compressed air

## 10.5 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Compressed air is used for the following:
  - ▶ Instrumental air system
  - ▶ House service air system
  - ▶ Soot blower system
2. Instrument air system is used for the following purposes:
  - ▶ Instrument air system supply
  - ▶ Distribution of air for power station equipment
3. Air-flow instrument is used for showing the quantity of air flow in the system.
4. The two uses of the house service air system are as follows:
  - ▶ For general use in the house
  - ▶ For burner ignitors

## 10.6 QUESTIONS AND EXERCISES

### Short-Answer Questions

1. What is the use of compressed air in a thermal power plant?
2. What is the method used by an air dryer to remove humidity?
3. Which type of compressor is usually adopted for instrument air compressors?

### Long-Answer Questions

1. Why is the volume of a receiver 1–2 times of the air consumption rate? Explain.
2. Describe the use of the home service air system.

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