SUPERHEATERS

The function of the superheater in the thermal power plant is to remove the last traces of moisture (1 to 2%) from the saturated steam coming out of boiler and to increase its temperature sufficiently above saturation temperature.

The super-heating raises overall cycle efficiency as well as avoids too much condensation in the last stages of the turbine which avoids the blade erosion.

The heat of combustion gases from furnace is utilized for the removal of moisture from steam and to superheat the steam. Super-heaters usually have several tube circuits in parallel with one or more return bends, connected between headers.
The steam is superheated by transferring the heat of gases either by convection or by radiation or by combined convection and radiation.

The combined type superheater has proved most desirable as it keeps the constant temperature throughout the load range.
The principle of convection superheater is similar to steam generating tubes of the boiler. The hot gases at high temperature sweep over superheater tubes and raise the temperature of steam which magnitude depends upon exit gas temperature leaving the superheater and gas-velocity.

The convection superheater may be set as "Interdeck Form" or "Overdeck Form".

The superheater is placed between the water tubes in interdeck arrangement

it is located above the water tubes in case of overdeck type.
A radiant superheater is located in the furnace wall and absorbs heat from the luminous fuel source just as the furnace wall tubes transmit radiant heat the saturated water in the wall tubes.

- Inerbank superheater
- Overdeck superheater
- Inertube superheater
The common methods used for controlling the superheat temperature of the steam are discussed below:

1. **Bypassing the furnace gas around the superheater.** At lower loads on the power plant, the part of the gases are bypassed with the help of damper as shown in Fig. (a). Until recently, this method of control was used successfully. But the troubles with satisfactory materials to withstand erosion and high temperatures in the gas passages have limited the use of damper method of control.

2. **Tilting burners in the furnace.** The temp. of the steam coming out of superheater is controlled by titling burners up or down through a range of 30°C as shown in Fig (b).

   By tilling the burner downward in a furnace much of the heat is given to the water walls by the gas and the gas entering the superheater region is relatively cool.

   If the burner is turned upward, then the heat given to the boiler water wall is less and hotter gas enters the superheater region to increase the steam temperature.
3. **Auxiliary burners.** The temperature of the steam can be controlled by turning the auxiliary burners in addition to main burners. The effect of this is similar to tilting burners. The arrangement is shown in Fig. (c).

4. **Desuperheater using water spray.** The temperature of the steam can be controlled by injecting the water either before the superheater or between sections of a superheater as shown in Fig. (d).
5. **Pre-condensing control.** The temperature of the steam can be controlled by condensing the steam coming out of the boiler with a small condenser with the help of feed water as shown in Fig. (e). Automatic control regulates the amount of feed water by-passed.

6. **Gas recirculation.** The gas coming out of the economiser is partly recirculated into the furnace with the help of a fan as shown in Fig. (F). The recirculated gas acts like excess air and blankets the furnace wall. This reduces the heat absorption by water wall and increases the heat absorption by superheater.
7. Twin furnace arrangement.
The twin furnace arrangement as shown in Fig. (g) is an extension of the separately fired superheater. Varying the firing rates between furnaces controls the superheat temperature.
REHEATERS

Function: The function of the re-heaters is to resuperheat the partly expanded steam from the turbine. This is done so that the steam remains dry as far as possible through the last stage of the turbine.

Location: Before or after the convective superheater in the convective zone of utility boilers.

In modern high pressure boilers, reheaters are generally in two sections. The primary section is placed in the convective zone and secondary section is placed just at the furnace exit hanging from the top.

The design consideration for reheaters are similar to those for superheaters. It having same output temperatures but steam pressures are about 20-25% of those in superheaters. Hence lower grade steel alloy can be used for reheaters.
ECONOMIZER

The first successful design of economizer was used to increase the steam-raising efficiency of the boilers of stationary steam engines. It was patented by Edward Green in 1845, and since then has been known as Green's economizer.

**Function:**

When the combustion gases leave the boiler after giving most of their heat to evaporator tubes, superheated tubes and reheater tubes, they still possess lot of heat, such heat used by this device to increases the temperature of feed water.

Economizers are so named because they can make use of the enthalpy in fluid streams that are hot, but not hot enough to be used in a boiler, thereby recovering more useful enthalpy and improving the boiler's efficiency.

Economizers are commonly used as part of a heat recovery steam generator in a combined cycle power plant.
Note: Boiler wall tubes are not shown for simplicity.
Classification of economizers:

1. Based on construction

(i) **Plain tube type economizers**: The external surface of tubes is kept clean and free from soot by soot scrapers moving up and down the economizer tubes. Otherwise, heat transfer resistance is increased, and the efficiency of the economizer decreases.

![Diagram of plain tube type economizer](image-url)
(ii) **Gilled tube type economizers:**
Rectangular gills are provided on the bare tube walls to increase the heat transfer surfaces.
2. Based on part of steam generation

(i) Steaming type economizers: some part of the water (about 5 to 7%) to be converted into steam during its passage through the economizer.

(ii) Non-steaming type economizers: While in case of non steaming economizer feed water is heated within 75% of the saturation temperature of the boiler.

3. Based on location of economizers

(i) Independent economizers: economizer is installed outside the boiler house at any convenient place

(ii) Integral economizers: economizer is installed close to the boiler.
Advantages of economizers:

(1) It improves the boiler efficiency. It has been found that about 1% efficiency of boiler is increased by increasing temperature of feed water by 6 °C with help of economiser.

(2) It reduces the losses of heat with the flue gases. The temperature of flue gases is about 370°C to 540°C at exit of last superheater or reheater, having large amount of heat energy which otherwise would have been wasted.

(3) It reduces the consumption of fuel. It has been estimated that about 1% of fuel costs can be saved for every 6 °C rise in temperature of the boiler feed water.

(4) It reduces thermal stresses in the boiler due to reduced temperature differential in the boiler.
AIR PRE-HEATERS

Function: The air preheaters are employed to recover the heat from the flue gases and this heat is utilized to increased the temperature of air before it supply to the furnace.

Location: An air preheater is placed between the economizer and the chimney and it extracts heat from the flue gases and transfers to air which is entering the furnace. The portion of the heat that otherwise would pass up the chimney to waste.

Advantage of pre-heating the air:
(1) It increases the temperature of the furnace gases, improves combustion rates and combustion efficiency.
(2) Air preheater extracts heat from the flue gases, and lowers stack temperatures thus improving the overall efficiency of the boiler. It has found that a drop of 20-22°C in the flue gases temperature increases boiler efficiency by 1%.
(3) The preheating air facilitates the burning of poor grades of fuel thus permitting a reduction in excess air.
(4) It increases steam generating capacity per unit m² of boiler surface.
(5) Increased thermal efficiency of plant and saving of fuel.
Types of air preheaters:

(1) Recuperative type:
(i) Plate type (ii) Tubular type

(2) Regenerative type

(1) Recuperative type air preheaters

In recuperative type of air preheaters, the two fluids (air and flue gases) are separated by heat transfer surface.

Recuperative type of air preheater is further classified as tubular type and plate type.
Tubular air preheater:

It consists of a large number of tubes rolled into sheets as shown in Fig. The flue gases flow through tubes and air is passed over the outer surface of the tubes in a direction opposite to that of flue gases flow.

The horizontal baffles are provided to increase time of contact which will help for higher heat transfer.

A soot hopper is fitted to the bottom of air heater casing to collect soot.
Plate type air preheater:

It consists of rectangular flat plates spaced from 1.25 cm to 2.5 cm apart formed alternate flue gases and air passages as shown in Fig.

This type of air preheater is more expensive for installation and maintenance compared to tubular type, hence it is not used in modern power plants.
**Regenerative** type air preheater has a energy storage medium called the matrix which is alternately exposed to the hot and cold fluids.

The rotor divided into a number of sectors (12 to 24 sectors), each sector being fixed with steel sheets.

The rotor is placed in a drum which has been divided into two compartments, air and flue gases compartments. To avoid leakage from one compartment to the other seals are provided.

The rotor rotates at a very slow speed of 3-4 rpm.
<table>
<thead>
<tr>
<th>Recuperator air preheater</th>
<th>Regenerative air preheater</th>
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<tbody>
<tr>
<td>(1) In this heat exchanger two fluids are separated by heat transfer surface. There is continuously heat transfer takes place.</td>
<td>(1) In this heat exchanger cold fluid and hot fluid alternately occupy same surface. There is discontinuously heat transfer takes place. First half time of cycle surface heated by gas and remain half cycle same surface cooled by air.</td>
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<tr>
<td>(2) Static construction, there is only nominal leakage through joints.</td>
<td>(2) Matrix are rotated, hence leakage through sealing arrangement at the moving surfaces is high.</td>
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<td>(3) It requires more space compared to regenerative type air preheater.</td>
<td>(3) Large heat transfer surfaces being accommodated in a small volume. Hence it is very compact air preheater.</td>
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<tr>
<td>(4) Less pressure drops for both air and flue gases.</td>
<td>(4) Large pressure drops for both air and flue gases.</td>
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<tr>
<td>(5) It does not required power since there is no any rotating parts.</td>
<td>(5) It needs power to rotate the matrix rotor.</td>
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<tr>
<td>(6) The cleaning the surface is difficult.</td>
<td>(6) The cleaning the surface is not difficult.</td>
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<tr>
<td>(7) It becomes very large as boiler capacity increases. Hence, for large power plant large size air preheater required.</td>
<td>(8) It is very economically used for high capacity boilers and plants.</td>
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Corrosion is the destructive conversion of metal into oxides or salts.

Corrosion may occur in the boiler shell, evaporating tubes superheater, economises and air preheaters.

The presence of $O_2$ is mostly responsible for corrosion among other factors. Oxygen generally enters a closed system through make up condenser leakage and condensate pump packings.

The $CO_2$ is next to $O_2$ which is responsible for corrosion, it comes out of bicarbonates on heating and it combines with water to form weak acid known as carbonic acid.

Hydrogen embrittlement of mild steel boiler tubing occurs in high-pressure boilers when atomic hydrogen forms at the boiler tube surface as a result of corrosion.

On the external surface of boiler accessory, corrosion generally depends on -ash properties, -rate of ash deposition, -tube surface temperature and -chromium percentage in the tube material.
Galvanic Corrosion
The most common type of galvanic corrosion in a boiler system is caused by the contact of dissimilar metals, such as iron and copper. These differential cells can also be formed when deposits are present. Galvanic corrosion can occur at welds due to stresses in heat-affected zones or the use of different alloys in the welds.

Caustic Corrosion
Concentration of caustic (NaOH) can occur either as a result of steam blanketing or by localized boiling beneath porous deposits on tube surfaces. 

*Steam blanketing is a condition that occurs when a steam layer forms between the boiler water and the tube wall. Under this condition, insufficient water reaches the tube surface for efficient heat transfer. The water that does reach the overheated boiler wall is rapidly vaporized, leaving behind a concentrated caustic solution, which is corrosive.*

Acidic Corrosion
Low makeup or feedwater pH can cause serious acid attack on metal surfaces in the preboiler and boiler system. Even if the original makeup or feedwater pH is not low, feedwater can become acidic from contamination of the system.
(1) **Corrosion at inner surfaces (water/steam side):** the corrosion is caused by
- an acid or low pH value in water and
- the presence of $O_2$, $CO_2$ or chlorides dissolved in feed water.

**Methods of inner surface corrosion prevention:**

(1) A proper designed deaerator combined with water treatment plant is used to remove the dissolved $O_2$, and $CO_2$.

(2) Dissolved oxygen can be removed by balanced amount of scavengers like hydrazine sodium sulphate.

(3) The effect of $CO_2$ is neutralized by the addition of ammonia for neutralizing amines in water.

(4) The corrosion of metal surfaces can be prevented by applying protective coating of amines to the internal surfaces of boilers tubes.
(2) Corrosion at inner surfaces (water/steam side): The external this is mainly caused by coal ash when the temperature range is between 540°C to 710°C. Alkali sulphates deposits on tube surfaces and corrosion starts.

High temperature of superheater and reheaters favour the formation of low-melting compounds like sodium or potassium iron. These corrosion is known as high temperature corrosion.

Low temperature corrosion may take place at economizer and air pre heater. External corrosion of the economizer tubes is very serious when high sulphur content wet fuels are used in the boiler furnace.

External corrosion also occurs if flue gases contains water vapour, which condenses at the tube surfaces. Sulphurous acid is formed when SO₂ is dissolved in free moisture in the flue gases.
Methods of external surface corrosion preventions:

(1) High temp corrosion may be reduce by using good quality of coal and selection of high grade metal alloys.

(2) Low temp corrosion can be prevented in economizer by pre heating the feed water by steam.

(3) To avoid corrosion of air pre heater temp of flue gases should not be fall down below the dew point temp.
MECHANICAL CONDITIONS AFFECTING CORROSION

Many corrosion problems are the result of mechanical and operational problems. The following practices help to minimize these corrosion problems:

- selection of corrosion-resistant metals

- reduction of mechanical stress where possible (e.g., use of proper welding procedures and stress-relieving welds)

- minimization of thermal and mechanical stresses during operation, within design load specifications, without over-firing, along with proper start-up and shutdown procedures

- maintenance of clean systems, including the use of high-purity feedwater, effective and closely controlled chemical treatment, and acid cleaning when required
**DEAERATOR**

- A **deaerator** is a device that is widely used for the removal of air and other dissolved gases from the feed water to steam-generating boilers. In particular, dissolved oxygen in boiler feed waters will cause serious corrosion damage in steam systems by attaching to the walls of metal piping and other metallic equipment and forming oxides (rust). Water also combines with any dissolved carbon dioxide to form carbonic acid that causes further corrosion. Most deaerators are designed to remove oxygen down to levels of 7 ppb by weight (0.0005 cm³/L) or less.

- There are two basic types of deaerators, the tray-type and the spray-type:
  - The *tray-type* (also called the *cascade-type*) includes a vertical domed deaeration section mounted on top of a horizontal cylindrical vessel which serves as the deaerated boiler feedwater storage tank.
  - The *spray-type* consists only of a horizontal (or vertical) cylindrical vessel which serves as both the deaeration section and the boiler feedwater storage tank.
Figure 1: A schematic diagram of a typical tray-type deaerator.
Figure 2: A schematic diagram of a typical spray-type deaerator.

A = Spray nozzle
B = Spray nozzle shroud
C = Baffle
D = Steam supply pipe
E = Preheating section
F = Deaeration section