SWAMI VIVEKANANDA SCHOOL OF ENGINEERING & TECHNOLOGY

LECTURE NOTE

POWER STATION ENGINEERING

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Introduction :

(1) Sources of energy :

(1) Fuels { Solids - coal, coke anthracite etc.
Liqueds - Petroleum and its derivates.
Gases - Natural gas, blast furnace gas etc.

(2) Energy stored in water.

3) Nuclear energy.

4) Wind Power.

5) Solar energy.

6) Tidal Power.

7) Geothermal energy.

8) Thermoelectric Power.

(1) classification of steam Power Plant :

1) central stations.

2) Industrial Power stations or captive Power stations.

1) central stations :

The electrical energy available from this stations is meant for general sale to the customers who which to Purchase it. Generally these stains are condensing type where the exhaust steam is discharged into a condenser insted of into the atmosphere. In the condenser the Pressure is exhaust steam is condensed.

(2) Captive Power stations:

This type of Power stations is run by a manufacturing company for its own use and its output is not available for general sale. Normally these plants are non-condensing because a large quantity of steam (low pressure) is required for different manufacturing operations

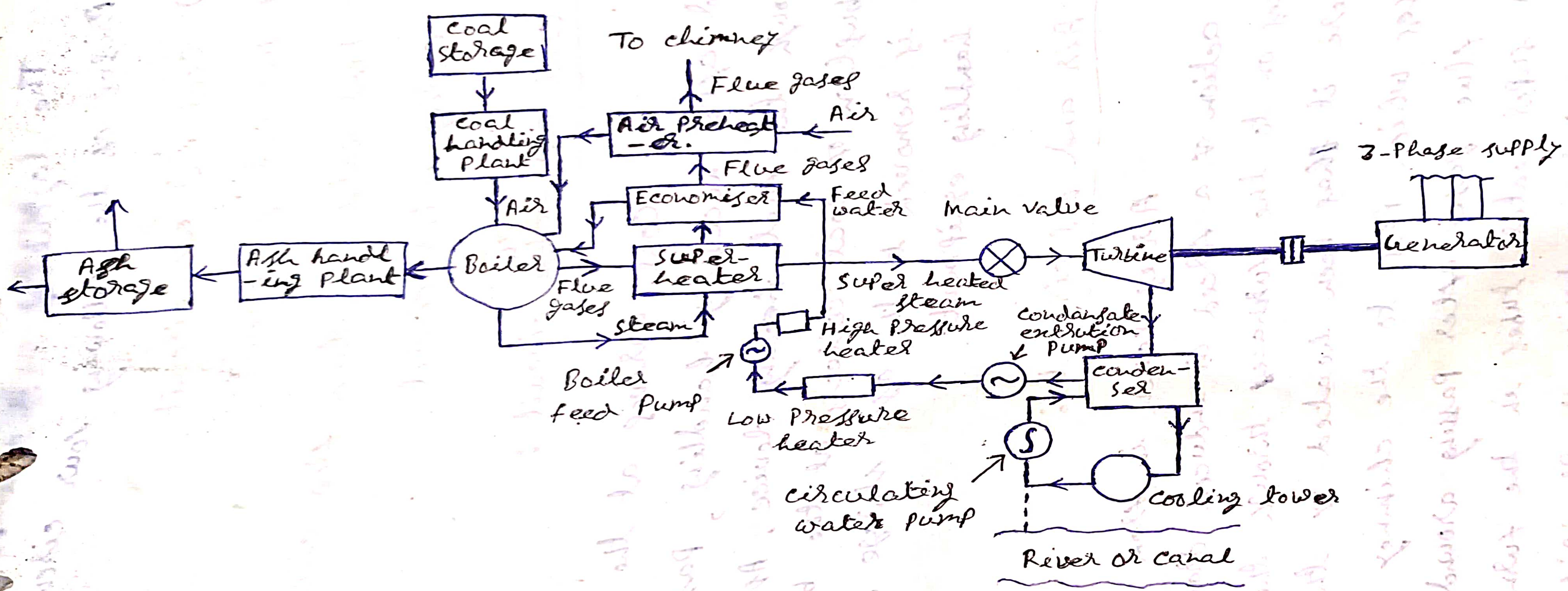
Advantages of condensing steam Power Plants:

(i) The amount of energy extracted per kg of steam is increased (a given size of the engine or turbine develops more power.).

(ii) The steam which has been condensed into water in the condenser, can be recirculated to the boiler which the help of pumps.

In non-condensing steam Power Plants a continuous supply of fresh feed water is required which becomes a problem at places where there is a shortage of pure water.

(III) Power Plant :



Layout of Steam Power Plant

comprises of the following four circuits :

(1) Coal and ash circuit.

(2) Air and gas circuit.

(3) Feed water and steam flow circuit.

(4) cooling water circuit.

(i) Coal and ~~water~~ ash circuit :

Coal arrives at the storage yard and after necessary handling, passes on the furnace through the fuel feeding device. Ash resulting from combustion of coal collects at the back of the boiler and is removed to the ash storage yard through ash handling equipments.

(ii) Air and gas circuit :

Air is taken in from atmosphere through the action of a forced or induced draught fan and passes on to the furnaces through the air preheater, where it has been heated by the heat of flue gases which pass to the chimney via the preheater. The flue gases after passing around boiler tubes and super heater tubes in the furnace pass through a dust catching device or precipitator, then through the economizer, and finally through the air preheater before being exhausted to the atmosphere.

In the water and steam circuit condensate leaving the condenser is first heated in a closed feed water heater through extracted steam from the lowest pressure extraction point of the turbines. It then passes through the deaerator and a few more water heaters before going into the boiler through economiser.

In the boiler drum and tubes, water circulates due to the difference between the density of water in the lower temp. and higher temp. sections of the boiler. Wet steam from the drum is further heated up in the superheater before being supplied to the primemover. After expanding in high pressure turbine steam is taken to the reheat boiler and brought to its original dryness or superheat before being passed on to the low pressure turbine. From there it is exhausted through the condenser into the hot well. The condensate is heated in the feed heaters using the steam trapped (bled steam) from different points of turbine.

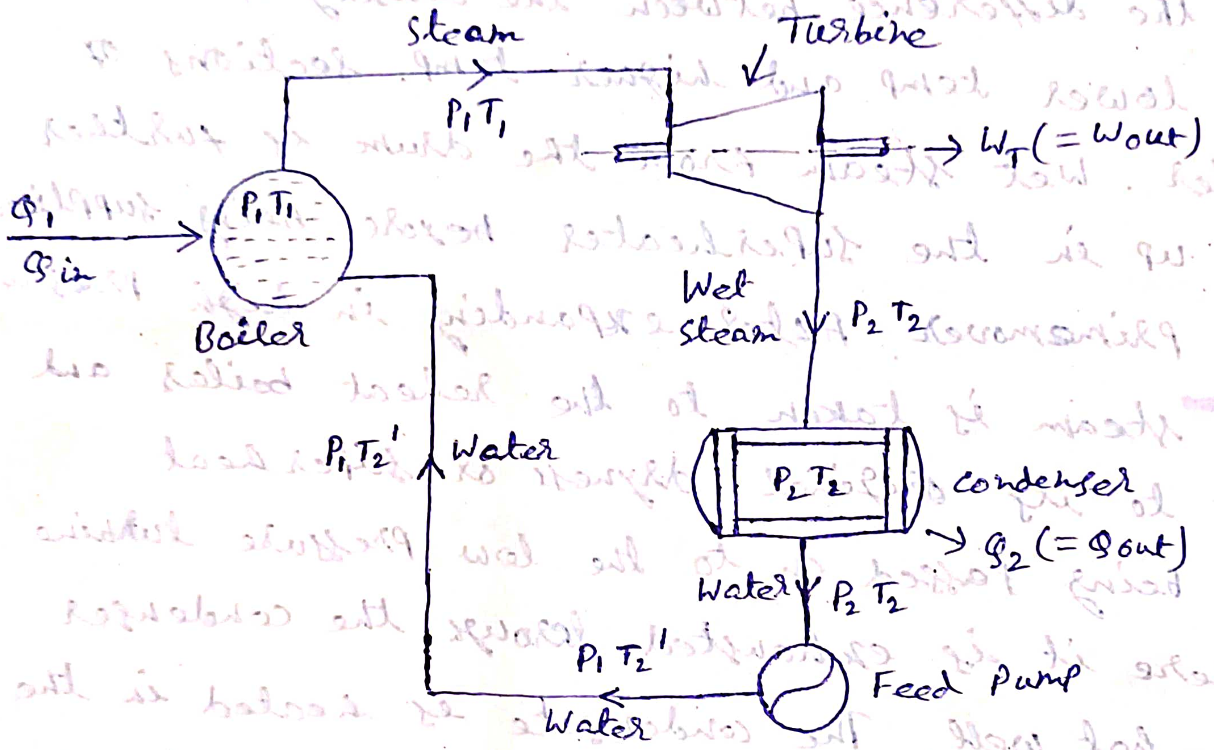
A part of steam and water lost and compensated by supplying additional feed water.

(iii) cooling water circuit :

The cooling water supply to the condenser helps in maintaining a low pressure in it. The water may be taken from a natural source such as river, leak or sea or the same water may be cooled power in cooling water.

(III) Steam Power cycle (Rankine cycle):

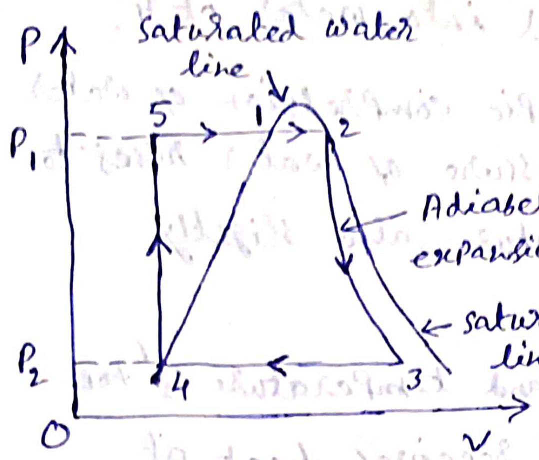
Rankine cycle in a modification of carnot cycle using steam as the working medium.
Rankine cycle is the theoretical cycle on which the steam turbine (or engine) works.



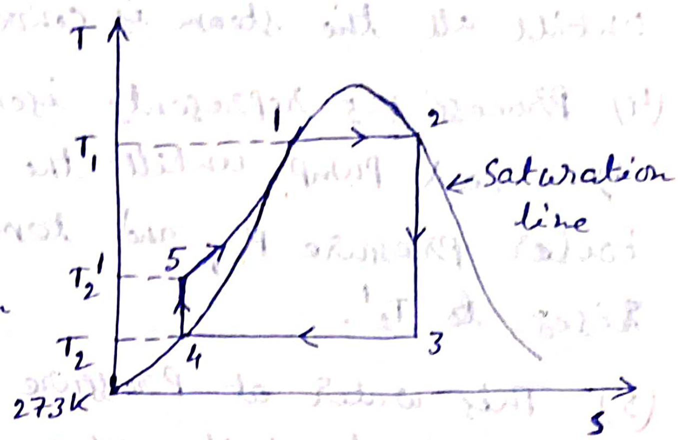
Schematic diagram for Rankine cycle

Description of Rankine cycle with the help of P-V diagram, T-S diagram and H-S diagram:

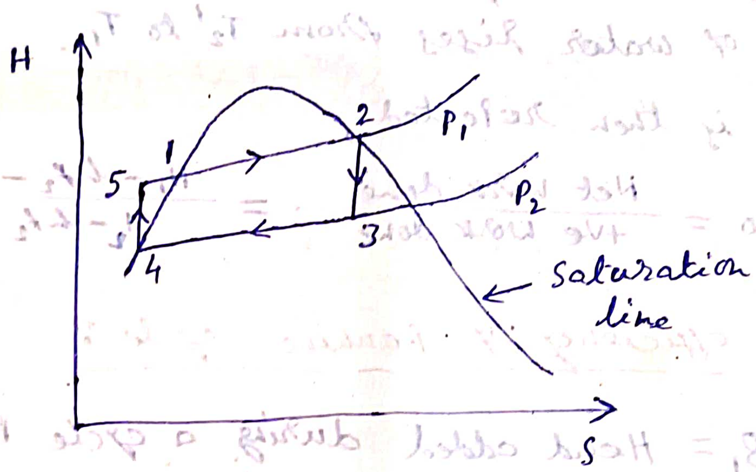
Steam used in the steam turbine has been shown to be dry saturated steam.



P-V diagram



T-S diagram



H-S diagram

The following is the sequence of operations of Rankine cycle:

(1) Process 1-2 represents addition of heat to water in a boiler. Water has already reached saturation temperature T_1 corresponding to boiler pressure P_1. Heat is added to water at constant temperature T_1 and constant pressure P_1 untill water is completely converted into steam (may dry shown by 2).

(2) Process 2-3 represents adiabatic expansion of steam in a steam turbine untill pressure of steam drops to back

(3) Process 3-4 represents condensation of steam in a condenser at constant pressure P_2 and constant temp. T_2 untill all the steam is converted into water at 4.

(4) Process 4-5 represents isentropic compression of water by a feed pump untill the pressure of water rises to boiler pressure P_1, and temperature also sligtly rises to T_2'.

(5) This water at pressure P_1 and temperature T_2' now enters into the boiler where it receives heat at constant pressure P_1 along the line 5-1 untill the temperature of water rises from T_2' to T_1.

The cycle is then repeated.

$$\text{Work ratio} = \frac{\text{Net work done}}{\text{+ve work done}} = \frac{H_1 - hf_2 - W_P}{H_2 - hf_2}$$

Thermal efficiency of Rankine cycle :

Let Q_1 = Heat added during a cycle per kg of steam.

Q_2 = Heat rejected " " " steam.

Then $Q_1 - Q_2$ = Heat utilised during the cycle per kg of steam.

Now, Thermal efficiency of a cycle is given by,

$$\eta_{th} = \frac{\text{Heat utilised}}{\text{Heat supplied}} = \frac{Q_1 - Q_2}{Q_1} \quad \text{--- (i)}$$

Let, H_1 = Total heat of 1 kg steam at 2 where pressure of steam is P_1 (admission pressure to the turbine) in KJ.

W_p = Work required to operate the feed pump.

The work is called feed pump work $= (P_1 - P_2) \times V_4$
(See P-V diagram) KJ/kg

Here, V_4 = Sp. volume of water at P_2 in m^3/kg.

Then, $Q_1 = H_1 - h_{f_2} - W_p$

Where, h_{f_2} = Heat of the liqued corresponding to back pressure P_2.

$$Q_2 = H_2 - h_{f_2}$$

$$\eta_{th} = \frac{(H_1 - h_{f_2} - W_p) - (H_2 - h_{f_2})}{H_1 - h_{f_2} - W_p}$$

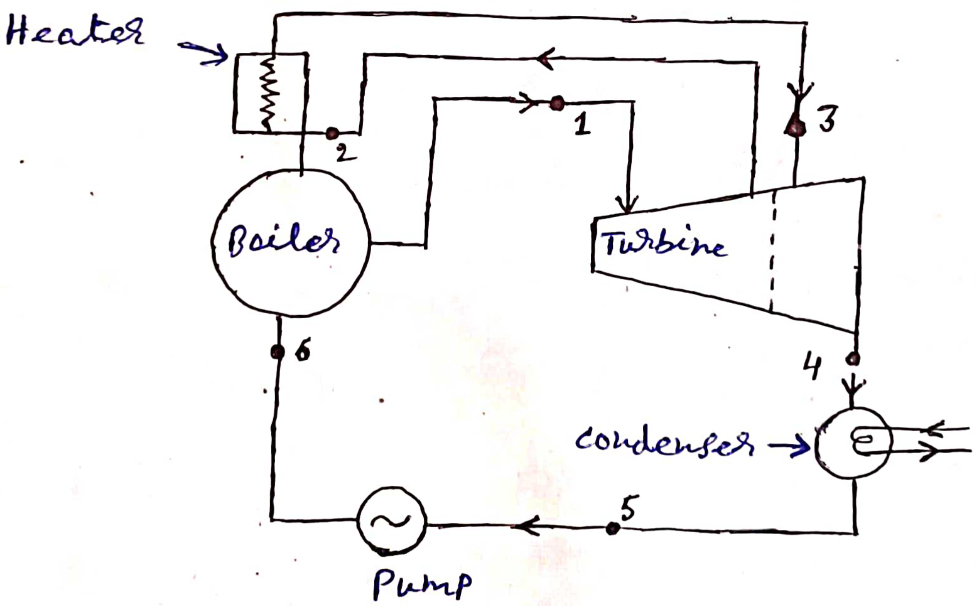
$$\therefore \eta_{th} = \frac{H_1 - H_2 - W_p}{H_1 - h_{f_2} - W_p}$$

(11) Reheat cycle :

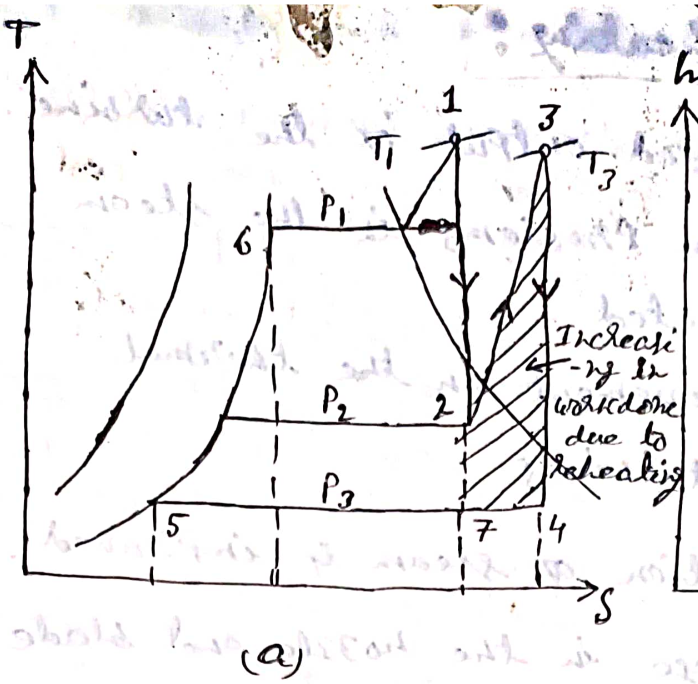
For attaining greater thermal efficiencies when the initial pressure of steam was rised beyond 42 bar it was found that resulting steam after, expansion was increasingly wetter and exceeded the safe limit of 12 percent condensation. It, therefore, become necessary to reheat the steam after part of expansion.

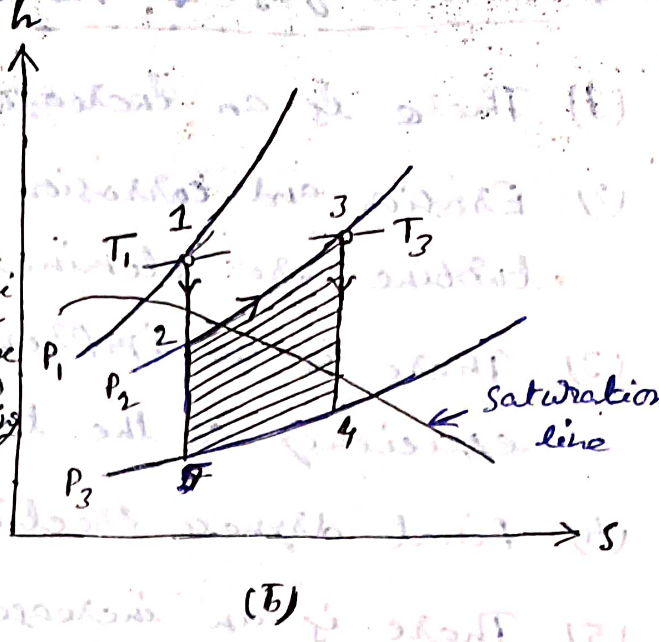
The reheating of steam is now universally used when ~~[illegible]~~ high pressure and temperature steam conditions such as 100 to 250 bar and 500 to 600°c are employed for throttled. For plants of still higher pressure and temperatures, a double reheating may be used.

In actual practice reheat improves the cycle efficiency by about 5% for a 85/15 bar cycle. The improvement of thermal efficiency due to reheat is greatly dependent upon the reheat pressure with respect to the original pressure of steam.



Schemetic diagram of a single stage reheat cycle.





Ideal reheating process on T-S and h-S chart

Figure (a) shows the formation of steam in the boiler. The steam as at state point 1 (pressure P_1 and temperature T_1) enters the turbine and expands isentropically to a certain pressure P_2 and temp. T_2. From this state point 2 the whole of steam is drawn out of the turbine and is reheated in a reheater to a temp. T_3. (Although there is an optimum pressure at which the steam should be removed for reheating, if the highest return is to be obtained, for simplicity whole steam is removed from the high pressure exhaust, where the pressure is about one fifth of boiler pressure, and after undergoing a 10% pressure drop, in circulating through the heater, it is returned to intermidiate pressure or low pressure turbine). This reheated steam is then readmitted to the turbine where it is expanded to condenser pressure isentropically.

Advantages of reheating:

(1) There is an increased output of the turbine.

(2) Erosion and corrosion problems in the steam turbine are eliminated.

(3) There is an improvement in the thermal efficiency of the turbines.

(4) Final dryness fraction of steam is improved.

(5) There is an increase in the nozzle and blade efficiencies.

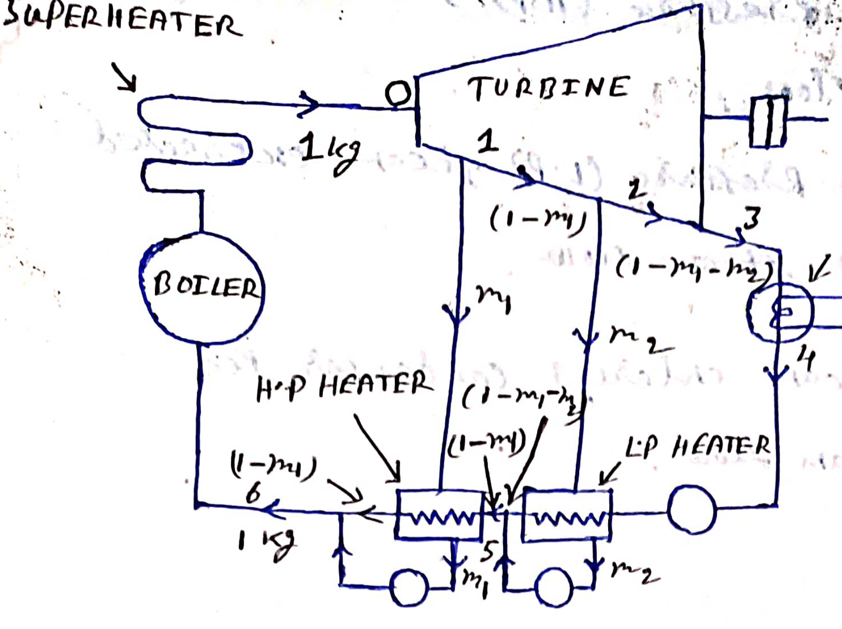
Disadvantages:

(1) Reheating requires more maintainance.

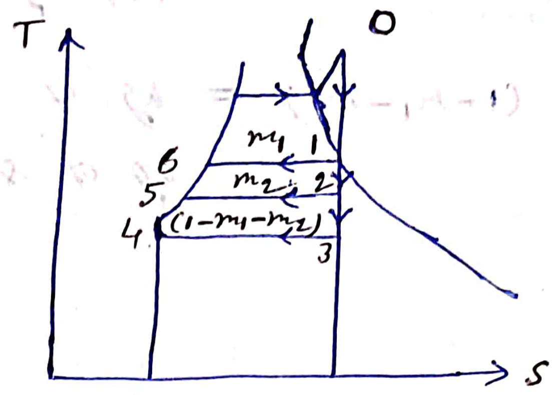
(2) The increase in thermal efficiency is not appreciable in comparision to the expenditure incurred in reheating.

(III) Regenerative cycle:

In the Rankine cycle it is observed that the condensate which is fairly at low temp. has an irreversible mixing with hot boiler water and this results in decrease of cycle efficiency. methods are, adopted to heat the feed water from the hot well of condenser irreversibly by interchange of heat within the system and thus improving the cycle efficiency. The heating method is called regenerative feed heat and the cycle is called regenerative cycle.



(a)



(b)

Regenerative cycle

The principle of regeneration can be practically utilised by extracting steam from the turbine at several locations and supplying it to the regenerative heaters. The resulting cycle is known as regenerative or bleeding cycle. The heating arrangement comprices of : (i) For medium capacity turbines - not more than 3 heaters, (ii) For high pressure high capacity turbines - not more than 5-7 heaters and (iii) For turbines of supercritical parameters 8-9 heaters are used.

The conditions of steam blead for each heater are selected so that the temp of saturated steam will be 4 to 10°c higher than the final condensate temp.

Fig (a) shows a diagrammetic layout of condensating steam power plant in which a surface condenser is used to condence all the steam that

Boilers :

A boiler may be defined as a closed vessel in which steam is produced from water by combustion of fuel.

According to the American socity of mechanical Engineers (A.S.M.E) a 'steam generating unit' is defined as,

" A combination of aparatus for producing, furnishing or recovering heat together with the apparatus for transferring the heat so made available to the fluid being heated and vaporized".

(///) classification of boilers :

(1) Horizontal, vertical or inclined :

The vertical boiler occupies less floor area.

(2) Fire tube and water tube :

In the fire tube boilers, hot gases are inside the tubes and the water surrounds the tubes. Exm: cochran, Lancashire, and locomotive boilers.

In the water tube boilers, the water is inside the tubes and hot gases surrounded them. Exm: Babcock and wilcox, stirling, yarrow boiler etc.

(3) Externally and internally fired :

The boiler is known as externally fired if the fired is outside the shell. Exm: Babcock and wilcox boiler, Stirling boiler etc.

In case of internally fired boilers, the furnace is located inside the boiler shell.
Exm: cochran, Lancashire boiler etc.

(4) Forced and natural circulation:

In forced circulation type of boilers, the circulation is done by a forced pump.
Exm: Velox, Lamount, Benson boiler etc.

In natural circulation type of boilers, circulation of water in the boiler takes place due to natural convection currents produced by the application of heat.
Exm: Lancashire, babcock and wilcox boiler etc.

(5) High pressure and low pressure boilers:

The boilers which produce steam at pressures of 80 bar and above are called the high pressures boilers.
Exm: Babcock and wilcox, velox, Lamount, Benson boilers etc.

The Boiler which produce steam at pressure below 80 bar are called low PR. boilers.
Exm: cochran, cornish, Lancashire and Locomotive boilers etc.

Stationary and Portable :

Primarily, the boilers are classified as either stationary (Land) or mobile (marine and Locomotive)

(7) Single and multi tube boilers :

The fire tube boilers are classified as fire tube and water-tube boilers, depending upon whether the fire tube is one or more than one.

Exm: cornish, ~~and~~ simple vertical boiler and rest of the boilers are multi-tube boilers.

(III) Accessories :

Accessories are the auxilary plants required for steam boilers for their proper operation and for the increase of their efficiency.

(a) Feed pump,
(b) Injector.
(c) Economiser.
(d) Air Preheater.
(e) Super heater.
(f) Steam separator.

(iii) Economiser :

Economiser is a device in which the waste heat of the flue gases is utilised for heating feed water. As the name indicates, the economiser improves the economy of the steam boiler

A well known type of economiser is green economiser. It is extensively used for stationary boilers, especially those of Lancashire boiler type. It consists of a large number of vertical pipes or tubes placed in an enlargement of the flue gases between the boiler and chimney as shown in fig. These tubes are 2.75 m long, 114 mm external dia and 11.5 mm thick and are made of cast iron.

The economiser is built up of transverse section. Each section consists of generally six or eight vertical tubes (1). This tubes are joined to horizontal pipes or boxes (2) and (3) at the top and bottom respectively. The top boxes (2) of the different sections are connected to pipe (4), while the bottom boxes are connected to pipe (5). The pipes (4) and (5) are opposite sides which are outside the brick work enclosing the economiser.

The feed water is pumped into the economiser at (6) and enters the pipe (5). It then passes into the bottom boxes (3) and then into the top boxes (2) through the tubes (1). It is now led by the pipe (4) to the pipe (7) and then to the boiler. There is a blow-off cock at the end of the pipe (5) opposite to the feed inlet (6). The purpose of this valve is to remove mud or sediment deposited in the bottom boxes. At the end of pipe (4) (opposite to the feed outlet) there is a safety valve.

P.T.O.