Thermal Engineering Lab Manual

Diploma

IVth Semester

Mechanical Engineering

Thermal Engineering LAB

List of Experiments:

1. To study low pressure boilers and their accessories and mountings.
2. To study high pressure boilers and their accessories and mountings.
3. To study the working of impulse and reaction steam turbines
4. To prepare heat balance sheet for given boiler.
5. To find power out put & efficiency of a steam turbine.
6. To find the condenser efficiencies.
7. To study cooling tower and find its efficiency.
8. To find calorific value of a sample of fuel using Bomb calorimeter.
9. Calibration of Thermometers and pressure gauges.
10. To study and find volumetric efficiency of a reciprocating air compressor.
11. To find dryness fraction of steam by separating and throttling calorimeter.

Experiment No: 1

AIM:- To study Low pressure Boiler and their mountings and accessories .

Apparatus: - Model of Cochran and Lancashire Boiler

Theory:-A steam boiler is a closed vessel in which steam is produced from water by combustion of fuel.

Classification of Boiler:

Boilers are classified on the basis of following-

1. According to contents in the Tube:

a) Fire tube boiler: In fire tube boilers, the flue gases pass through the tube and water surround them.

b).Water tube boiler: In water tube boiler, water flows inside the tubes and the hot flue gases flow outside the tubes.

2. According to the pressure of steam:

a). Low pressure boiler: A boiler which generates steam at a pressure of below 80 bars is called low pressure boiler. Examples-Cochran boiler, Lancashire boiler etc.

b). High pressure boiler: A boiler which generates steam at a pressure higher then 80 bar is called high pressure boiler. Example- Babcock and Wilcox boiler etc.

COCHRAN BOILER:

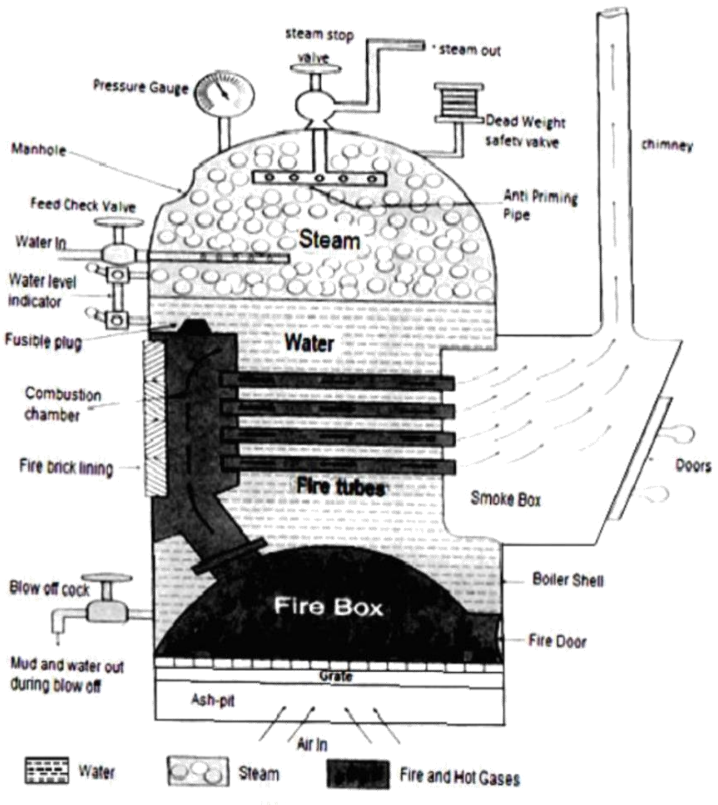
Cochran boiler is a vertical, multitublar fire tube, internally fired, natural circulation boiler.

Construction:

Figure shows a Cochran boiler. It consists of a vertical cylindrical shell having a hemispherical top and furnace is also hemispherical in shape. The fire grate is arranged in the furnace and the ash pit is provided below the grate. A fire door is attached on the fire box. Adjacent to the fire box, the boiler has a combustion chamber which is lined with fire bricks. Smoke or fire tubes are provided with combustion chamber. These tubes are equal in length and arranged in a group with wide space in between them. The ends of these smoke tubes are fitted in the smoke box. The chimney is provided at the top of the smoke box for discharge of the gases to the atmosphere. The furnace is surrounded by water on all sides except at the opening for the fire door and the combustion chamber. The smoke tubes are also completely surrounded by water. Different boiler mountings and accessories are located at their proper place.

Working:

The hot gas produced from the burning of the fuel on the grate rises up through the flue pipe and reaches the combustion chamber. The flue gases from the combustion pass through the fire tubes and the smoke box and finally are discharged through the chimney. The flue gases during their travel from fire box to the chimney gives heat to the surrounding water to generate steam.



COCHRAN BOILER

Specification of Cochran Boiler:

Diameter of the drum → 0.9 m to 2.75 m

Steam pressure → 6.5 bar to 15 bar

Lancashire boilers:

Lancashire is a stationary fire tube, internally fired, horizontal, natural circulation boiler. It is a commonly used in sugar – mills and textiles industries where along with the power steam and steam for the process work is also needed.

The specifications of Lancashire boiler are given below:

Diameter of the shell – 2 to 3 m. Length of the shell – 7 to 9 m Maximum working pressure – 16 bar Steam capacity – 9000 kg/h

Efficiency – 50 to 70 %

Lancashire boiler consists of a cylindrical shell inside which two large tube are placed. The shell is constructed with several rings of cylindrical from and it is placed horizontally over a brick work which forms several channels for the flow of hot gasses. These two tubes are also constructed with several rings of cylindrical form. They pass from one end of the shell to other end all covered with water. The furnace is placed at the front end of the each tube and they are known as furnace tubes. The coal is introduced through the fire hole into the great. There is a low brick work fire bridge at the back of the gate to prevent the entry of the burning coal of ashes into interior of the furnace tubes. The combustions from the grate pass up to the back end of the furnace tube and then in downward direction. There after they move through the bottom channel or bottom flue upto the front end of the boiler where they are divided and pass upto the side flues.

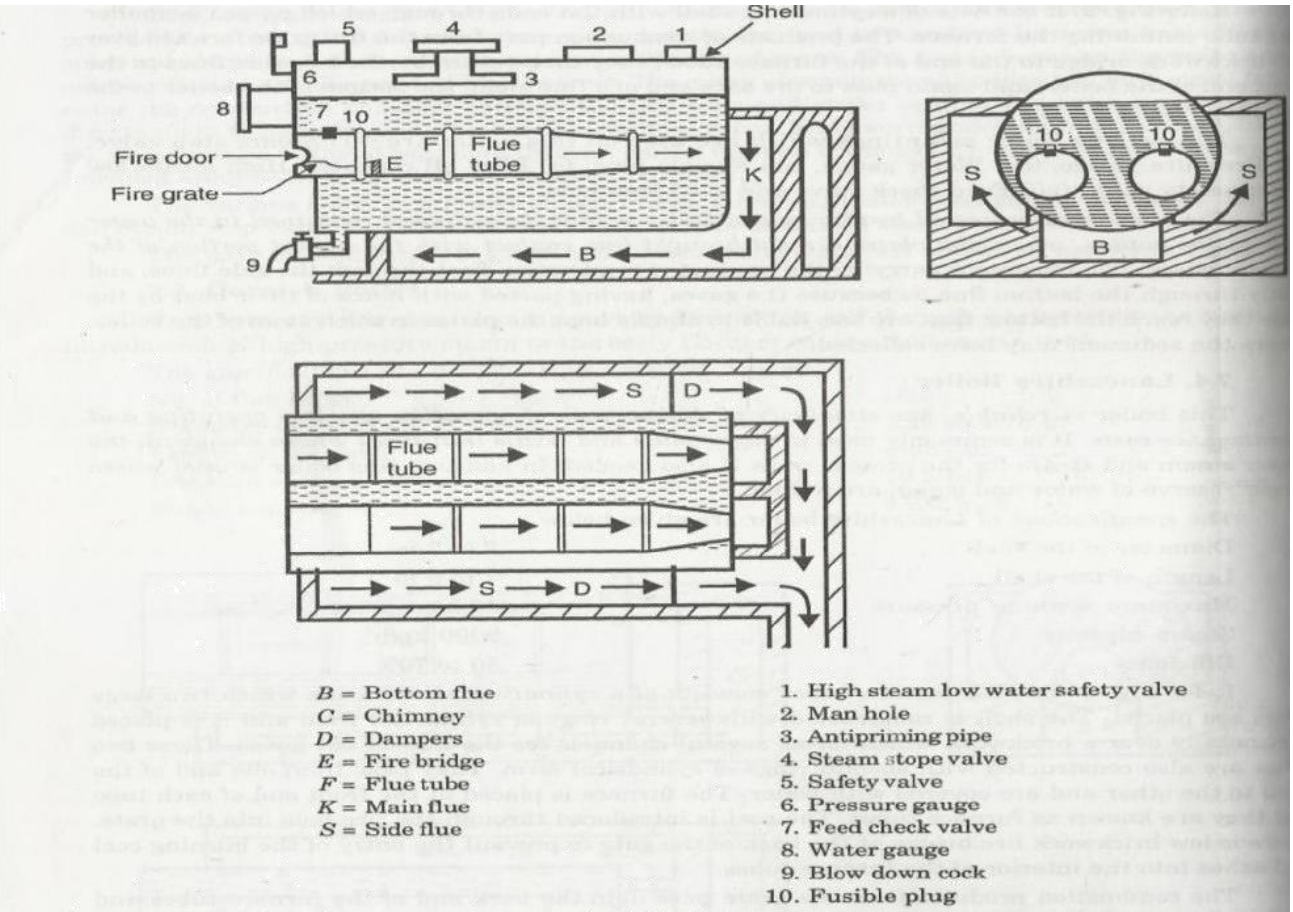


Fig. 4. Lancashire boiler.

BOILER MOUNTINGS: -

The components which are fitted on the surface of the boiler for complete safety and control of steam generation process are known as boiler mountings. The following are the various important mountings of a boiler.

Fusible Plug:-

It is fitted to the crown plate of the furnace of the fire. The function of fusible plug is to extinguish the fire in the fire box, when water level in the boiler comes down the limit and it prevents from blasting the boiler, melting the tube and over heating the fire-box crown plate. A fusible plug is shown in fig. It is located in water space of the boiler. The fusible metal is protected from direct contact of water by gun metal plug and copper plug. When water level comes down, the fusible metal melts due to high heat and copper plug drops down and is held by gun metal ribs.Steam comes in contact with fire and distinguishes it. Thus it prevents boiler from damages.

Blow off Cock:

The blow off cock as shown in fig., is fitted to the bottom of a boiler drum and consists of a conical plug fitted to body or casing. The casing is packed, with asbestos packing, in groves round the top and bottom of the plug. The asbestos packing is made tight and plug bears on the packing. Blow off cock has to principle function are:

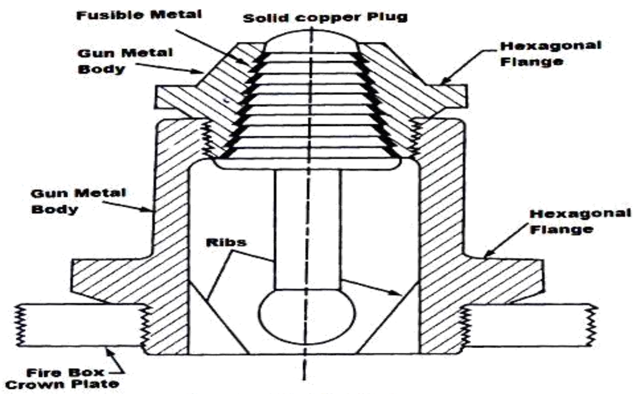


Figure- Fusible Plug

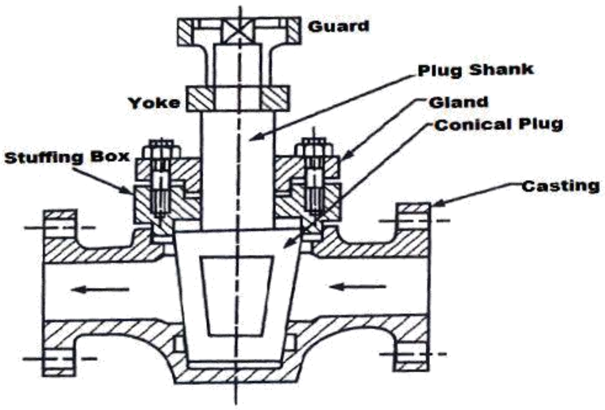


Figure- Blow Off Cock

BOILER ACCESSORIES:

The appliances installed to increase the efficiency of the boiler are known as the boiler accessories. The commonly used accessories are:

Economiser:

Economiser is a one type of heat exchange which exchanges the some parts of the waste heat of flue gas to the feed water. It is placed between the exit of the furnace and entry into the chimney. Generally economiser is placed after the feed pump because in economiser water may transfer into vapour partially, which creates a priming problem in feed pump water into the boiler drum. If economiser is used before feed pump it limits the temperature rise of water. It consists of vertical cast iron tubes attached with scraper. The function of scraper is to remove the root deposited on the tube, mechanically.

Air Pre-heater:-

The function of air pre-heater is to increase the temperature of air before it enters the furnace. It is installed between the economiser and the chimney. The air required for the purpose of combustion is drawn through the air pre-heater and its temperature is raised when passed through ducts. The preheated air gives higher furnace temperature which results in more heat transfer to the water and reduces the fuel consumption. There are three types of pre-heaters.

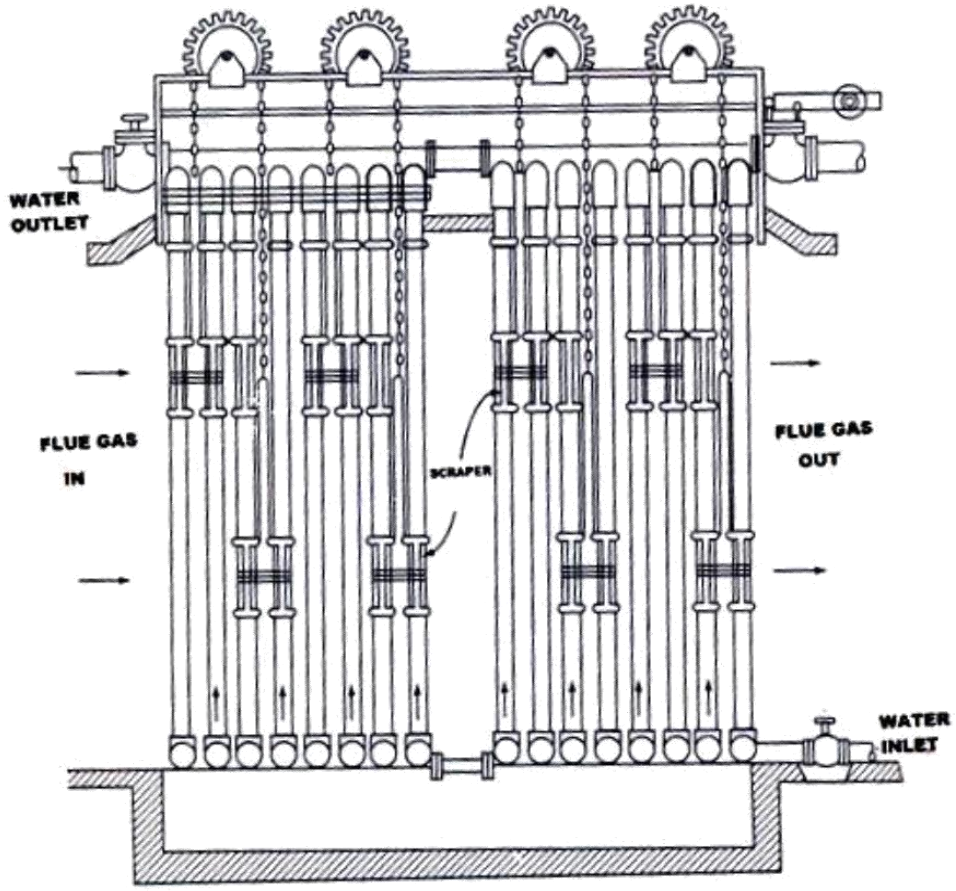


Figure- Economiser

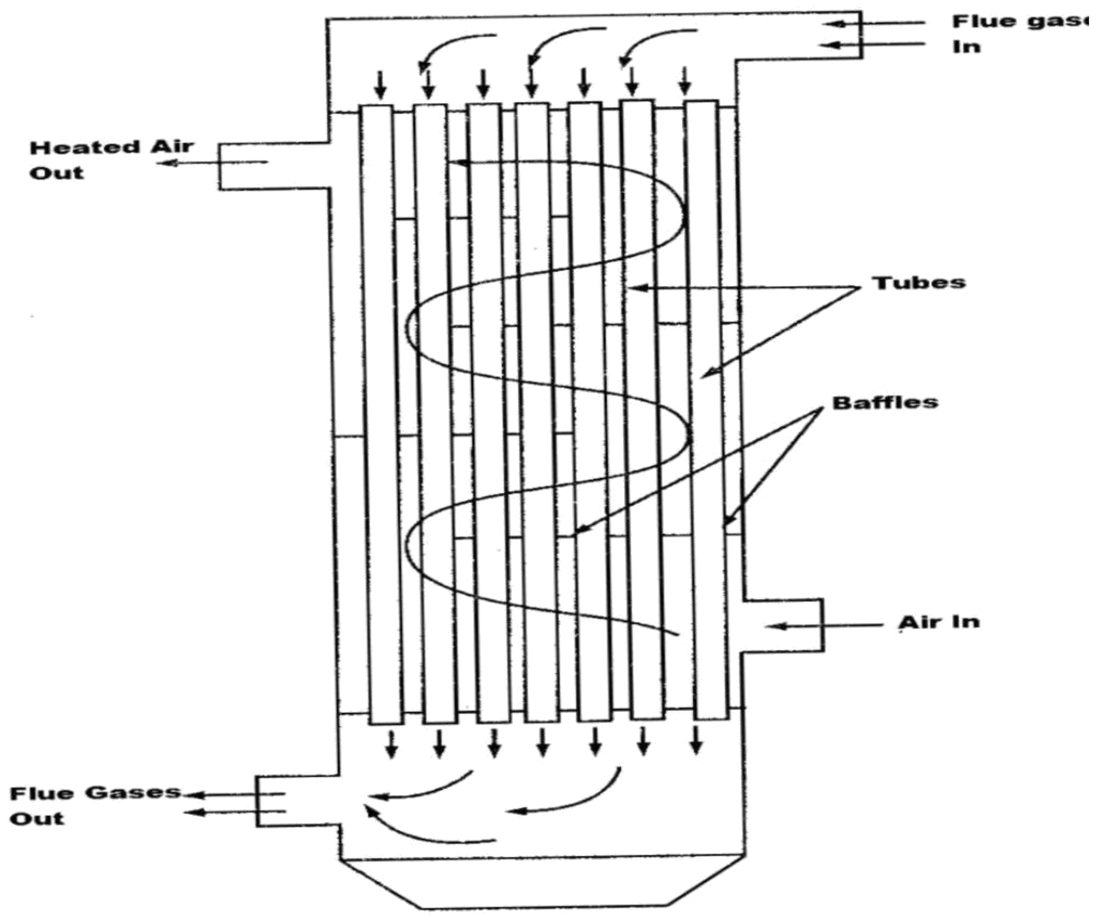


Fig- Tubular Type Air Pre-Heater

Experiment No: 2

AIM:-To study the working and construction of high pressure Boiler.

Apparatus: - Model of Babcock & Wilcox Boiler.

High pressure boiler: A boiler which generates steam at a pressure higher then 80 bar is called high pressure boiler. Example- Babcock and Wilcox boiler etc.

BABCOCK AND WILCOX BOILER:
Babcock and Wilcox boiler is a horizontal shell, multitubular, water tube, externally fired, natural circulation boiler.

Construction:

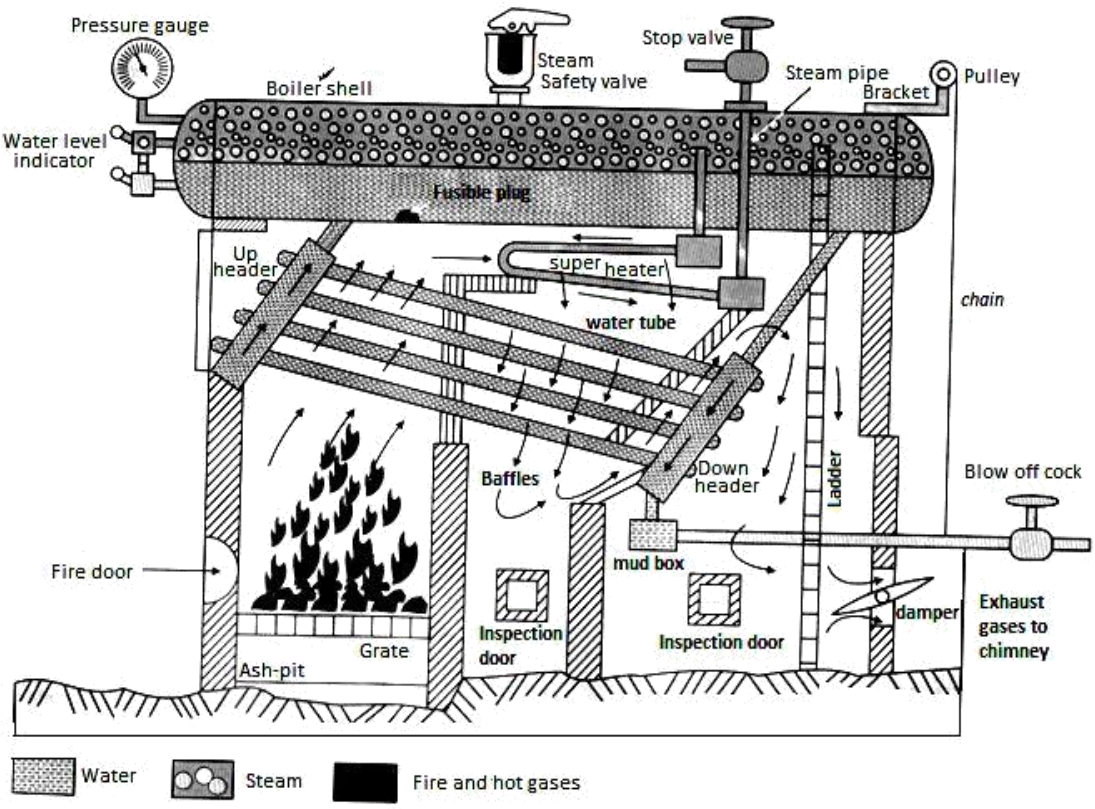
Figure shows the details of a Babcock and Wilcox water tube boiler. It consists of a drum mounted at the top and connected by upper header and down take header. A large number of water tubes connect the uptake and down take headers. The water tubes are inclined at an angle of 5 to 15 degrees to promote water circulation. The heating surface of the unit is the outer surface of the tubes and half of the cylindrical surface of the water drum which is exposed to flue gases.

Below the uptake header the furnace of the boiler is arranged. The coal is fed to the chain grate stoker through the fire door. There is a bridge wall deflector which deflects the combustion gases upwards. Baffles are arranged across the water tubes to act as deflectors for the flue gases and to provide them with gas passes. Here, two baffles are arranged which provide three passes of the flue gases. A chimney is provided for the exit of the gases. A damper is placed at the inlet of the chimney to regulate the draught. There are superheating tubes for producing superheated steam. Connections are provided for other mounting and accessories.

Working:

The hot combustion gases produced by burning of fuel on the grater rise upwards and are deflected by the bridge wall deflector to pass over the front portion of water tubes and drum. By this way they complete the first pass. With the provision of baffles they are deflected downwards and complete the second pass. Again, with the provision of baffles they rise upwards and complete the third pass and finally come out through the chimney. During their travel they give heat to water and steam is formed. The flow path of the combustion gases is shown by the arrows outside the tubes. The circulation of water in the boiler is due to natural circulation set-up by convective currents (due to gravity). Feed water is supplied by a feed check valve.The hottest water and steam rise from the tubes to the uptake header and then through the riser it enters the boiler drum. The steam vapours escape through the upper half of the drum. The cold water flows from the drum to the rear header and thus the cycle is completed.

To get superheated steam, the steam accumulated in the steam space is allowed to enter into the super heater tubes which are placed above the water tubes. The flue gases passing over the flue tubes produce superheated steam. The steam thus superheated is finally supplied to the user through a steam stop valve.



Babcock and Wilcox Boiler

Specification of Babcock and Wilcox Boiler:

Diameter of the drum	-	1.22 m to 1.83 m
Length of the drum	-	6.096 to 9.144 m
Size of water tubes	-	7.62 to 10.16 cm
Size of super heater tube	-	3.84 to 5.71cm
Working pressure	-	100bar
Steaming capacity	-	40,000 Kg/hr (Maximum)
Efficiency	-	60 to 80%

BOILER MOUNTINGS: -

The components which are fitted on the surface of the boiler for complete safety and control of steam generation process are known as boiler mountings. The following are the various important mountings of a boiler.

Steam Stop Valve-

A valve placed directly on a boiler and connected to the steam pipe which carries steam to the engine or turbine is called stop valve or junction valve. It is the largest valve on the steam boiler. It is, usually, fitted to the highest part of the shell by means of a flange as shown in fig.

The principal functions of a stop valve are:

1. To control the flow of steam from the boiler to the main steam pipe.
2. To shut off the steam completely when required.

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

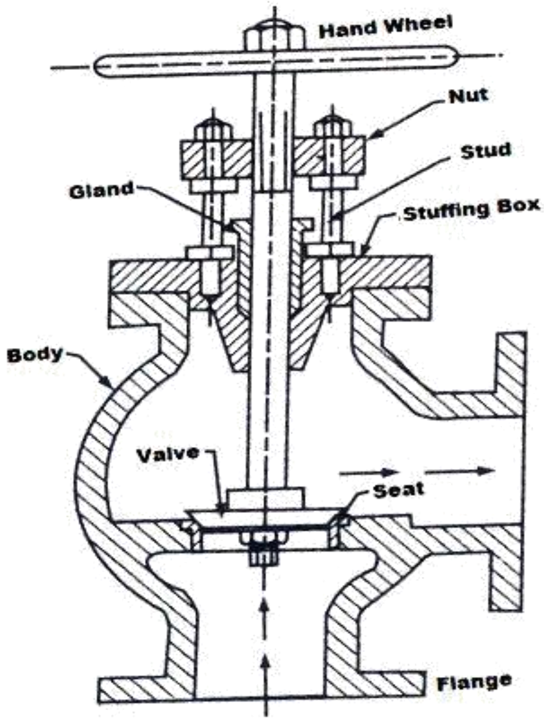


Figure-Steam Stop Valve

BOILER ACCESSORIES:

The appliances installed to increase the efficiency of the boiler are known as the boiler accessories. The commonly used accessories are:

Steam Injector-

An injector is a device which is used to lift and force water into a boiler i.e. operating at high pressure. It consists of a group of nozzles, so arranged that steam expanding in these nozzles imparts its kinetic energy to a mass of water. There are many advantages of using injector such as they occupy minimum space, have low initial costs and maintenance cost. Though the steam required to operate the injector is much more than that in the feed pump for an equivalent duty; the injector has the advantage that practically the whole of the heat of the steam is returned back to the boiler.

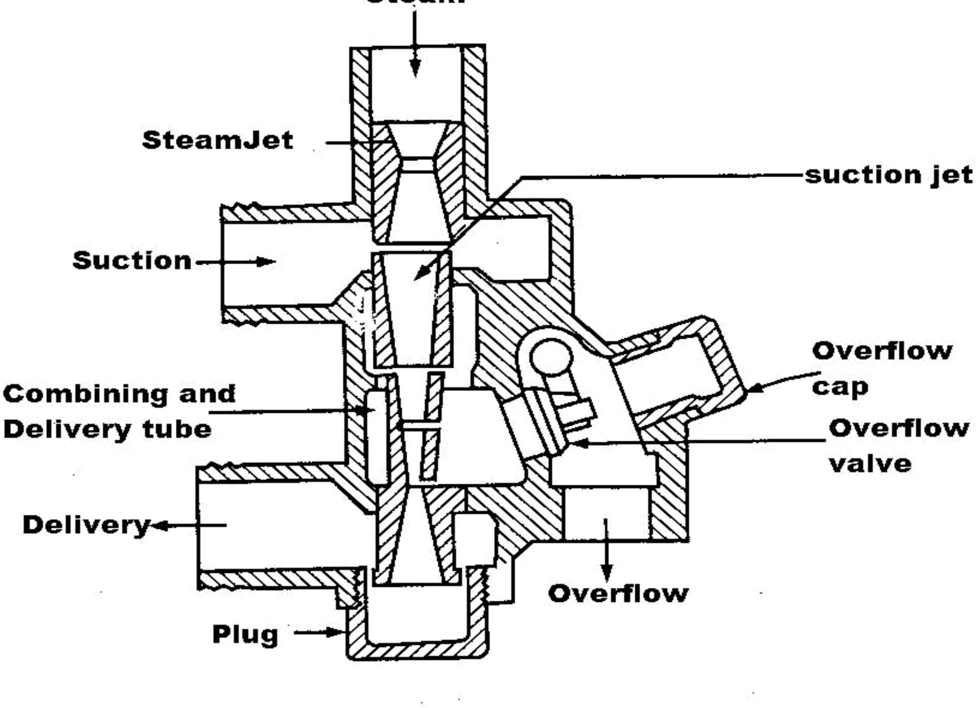


Figure- Injector

RESULT: We have studied successfully of high pressure boiler and their mounting and accessories.

Experiment No: 3

Aim: To Study the working of Impulse and Reaction steam turbines.

Apparatus: Model of Impulse and Reaction steam turbines.

Theory:

Steam turbines: The steam turbine is a prime mover in which the potential energy of steam is transformed into kinetic energy and latter in its turn is transformed into the mechanical energy of the rotation of the turbine shaft.

Classification of steam turbine: With respect to the action of steam, turbines are classified as:

- Impulse turbine
- Reaction turbine

1. **Impulse turbine:-**

It is a turbine, which runs by the impulse of steam jet. In this turbine, the steam is first made to flow through a nozzle. Then the steam jet impinges on the turbine blades with are curved like bucket and are mounted on the circumference of the wheel. The steam jet after impinges glide over the concave surface of blades and finally leave the turbine. The top portion of Impulse turbine exhibits a longitudinal section through the upper half, the middle portion shows one set of nozzle which is followed by a ring of moving blades, while lower part indicate changes in press and velocity during the flow of steam through the turbine. The principle equation of this turbine is the well known "De Laval" turbine.

2. **Reaction turbine:-**

In a Reaction turbine, the steam enters the wheel under pressure and flow over the blades. The steam while gliding proper the blades and then makes them to move. The turbine runner is rotated by the reactive forces of steam jets. In this, there is a gradual pressure drop takes place continuously over the fixed and moving blades. The fuel of fixed blades is that they after allow it expand to a larger velocity as the steam passes over the moving blades. Its K.E. is absorbed by them a three stage Reaction turbine

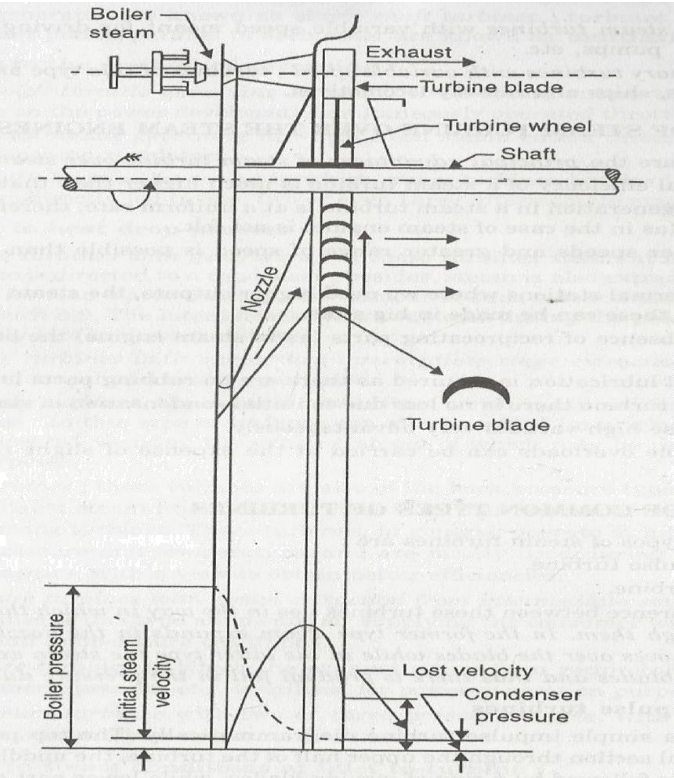


Fig. 1. Simple impulse turbine.

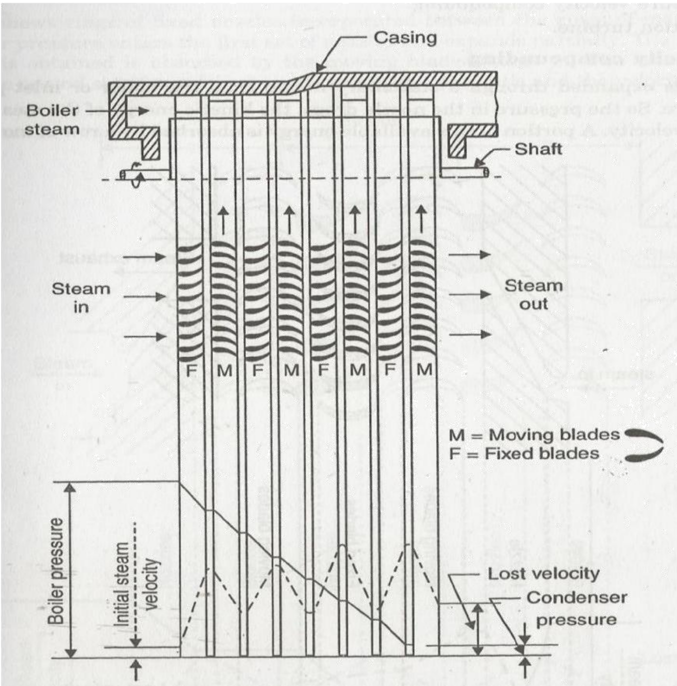


Fig. 2. Reaction turbine (three stage).

Compounding:- If the steam is expended from the boiler pressure in one stage the speed of rotor becomes tremendously high which drop up practical complicacies. The several methods of reducing this speed to lower value, all these methods utilized a multiple system of rotor in series. Keyed on a common shaft and the steam pressure or jet velocity is absorbed in stage as the steam flows over the blades, this is known as compounding.

a) Velocity compounding:-

Steam is expanded through a stationary nozzle from the boiler or inlet pressure to condenser pressure. So the pressure in the nozzle drops, the K. E. of steam increase due to increase in velocity. A portion of this available energy is absorbed by a row of moving blades. The steam then flow through the second row of the blades which are fixed. They redirect the steam flow without altering its velocity to the following nearest row moving blades. Where again work is done on them and steam with a low velocity from the turbine.

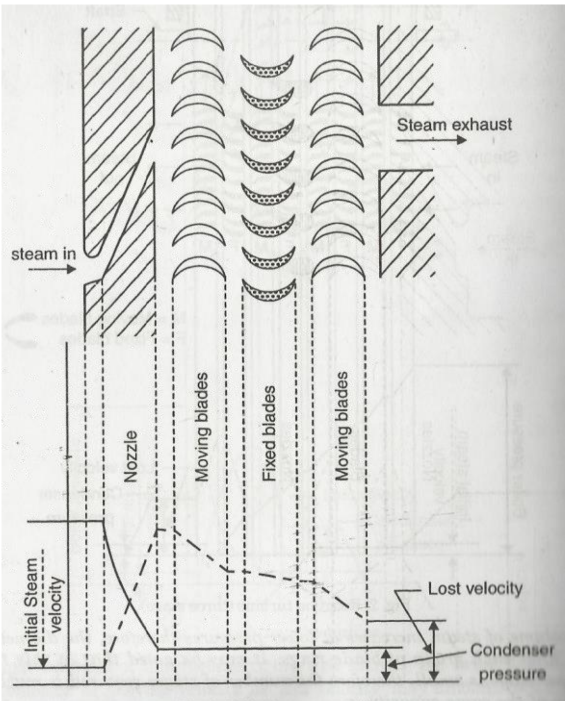


Fig. 3. Velocity compounding.

b) **Pressure compounding:-**

In this rings of fixed nozzle incorporated between ring of moving blades. The steam of boiler pressure enters the first set of nozzle and expands partially. The K.E. of steam thus obtained in absorbed by the moving blades. The steam then expands partially in the second set of nozzles whose its pressure again falls and the velocity increases. The K.E. thus obtained is observed by the second ring of moving blades. This is repeated in stage 3 and steam finally leaves the turbine at low velocity and pressure.

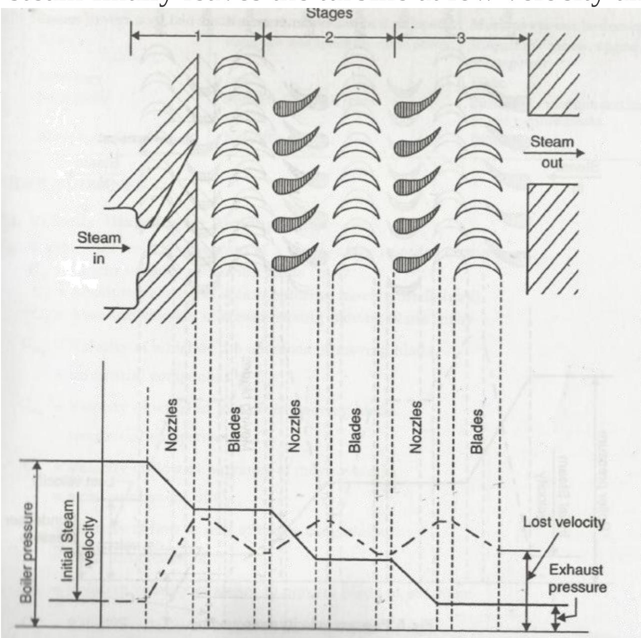


Fig. 4. Pressure compounding.

c) **Pressure-Velocity compounding:-**

This method is the combination of velocity and pressure compounding. The total drop in steam pressure is divided into stages and velocity obtained in each stage is also compounded. The ring of nozzle, are fired at beginning of each stage and pressure remains constant during each stage.

Conclusion: Thus, the study is completed for the working of Impulse and Reaction steam turbines.

Experiment 04

Aim: To prepare heat balance sheet for a given Boiler.

Theory- Efficiency of a boiler is the ratio of heat utilized in producing steam to he heat liberated in the furnace. Also the heat utilized is always less than heat liberated in the furnace.

The difference of heat liberated in the furnace and heat utilized is known as heat loss in the boiler.

The following are important losses:

1. Heat loss in dry flue gases

$= m_g \times c_{pg}(t_g - t_b)$

Where m_g= Mass of dry flue gases per kg of fuel,

C_{pg}= Mean specific heat of dry flue gases,

T_g= Temperature of flue gases leaving chimney

T_b= Temp. of boiler room

2. Heat lost in moisture present in the fuel

$= m_m(h_{sup} - h_b)$

$= m_m[h_g + c_p(t_g - t) - h_b]$

$= m_m[2676 + c_p(t_g - 100) - h_b]$

Where m_m = Mass moister per kg of fuel

C_p = Mean specific heat of superheated steam in flue gases,

H_b = Enthalpy of water at boiler room temp.

3. Heat lost to steam formed by combustion of hydrogen per kg of fuel

$= 9H_2[2676 + c_p(t_g - 100) - h_b]$

4. Heat loss due to unburnt carbon in ash pit

$= m_1 \times c_1$

Where m_1 = mass of carbon in ash pit per kg of fuel

C_1 = calorific value of carbon

5. Heat loss due incomplete combustion of carbon to carbon monoxide

$= m_2 \times c_2$

Where m_2= mass of carbon monoxide in flue gas per kg of fuel

C_2= calorific value of carbon monoxide

Numerical-

Draw the heat balance sheet from the data given below which boiler generating 500 kg/hr of steam at 10.5 bar pressure and 0.97 dryness fraction.

Fuel used and its calorific value	: 75kg/hr and 31500KJ/kg
Moisture present in the fuel	: 6% by mass
Mass of dry flue gases	: 10kg/kg of fuel
Temp. of flue gases	: 315°C
Specific heat of flue gases	: 1.1 KJ/kgK
Temperature of boiler room	: 38°C
Feed water temperature	: 50°C

Solution

Given: p= 10.5 bar; m_s= 500kg ; m_f= 75kg/hr ; m_m= 0.06 kg/kg of fuel ; m_g= 10kg/kg of fuel ; C= 31500KJ/kg ; t_g= 315°C; t_b= 38°C; t_1 = 50°C ; c_{pg}= 1.1 KJ/kgK; x= 0.97

Heat supplied per kg of fuel

$$= (1-0.06)31500$$

$$= 29610 \text{ KJ}$$

1. Heat utilized in raising steam per kg of fuel: m_e =

   m_s/m_f = 500/75 = 6.67 kg

   From steam table enthalpy of feed water at 50ºC H_f = 209 KJ/kg
   Enthalpy of steam at 10.5 bar
   H_f = 772.0 KJ/kg H_{fg} = 2006.0 KJ/kg

   Heat utilized in raising steam per kg of fuel

   $$= m_e(h-h_{f1}) = m_e(h_f+xh_{fg}-h_{f1})$$

   $$= 6.67(722 + 0.97\times2006 - 209)$$

   $$= 16740 \text{ KJ/kg of fuel}$$

2. Heat carried by dry flue gas
   $$= m_g\times c_{pg}(t_g-t_b)$$
   $$= 10\times1.1(315-38) = 3047 \text{ KJ/kg of fuel}$$
3. Heat lost in moisture present in the fuel per kg of fuel
   From steam table at 38ºC H_b =159.1 KJ/kg
   $Q_m = m_m[2676 + c_p(t_g-100) – h_b]$
   =0.06[2676 + 2.1(315-100) -159.1]
   =178.1 KJ/kg of fuel
4. Heat lost by radiation:
   =29610 – (16740 + 3047 + 178.1)
   =9644.9 KJ/kg of fuel
   =

Heat supplied	KJ	Heat Expenditure	KJ	%
Heat supplied 1 kg of fuel	29610	1. Heat utilized in raising steam	16740.00	56.33
		2. Heat carried by dry flue gas	3047.00	10.29
		3. Heat lost in moisture present in the fuel per kg of fuel	178.10	0.60
		4. Heat lost by radiation	9644.90	32.57
			29610.00	100%

Experiment No: 5

Aim: To find power output & efficiency of a steam turbine.

Theory: A steam turbine is a device that takes hot, high-pressure steam and extracts mechanical energy from it. This energy can then be used to do useful work that uses steam turbines is the steam power plant, which generates electricity used in everyday life.

Work done on the blade

The work done on the blade may be found out from the change of momentum of the steam jet during its flow over the blade.

From Newton's second law of motion

Force on the wheel = mass of steam × acceleration

= mass of steam/sec. × change of velocity.

$= m \{c_{w1} - (-c_{wo})\}.$

$= m (c_{w1} + c_{wo})$

Work done on the blade per second = force × distance travelled/sec.

$= m (c_{w1} + c_{wo}) \times c_{bl}$

Blade efficiency $= 2c_{bl}(c_{w1} + c_{w2})/c_1^2$

Example 1. *In a De Laval turbine steam issues from the nozzle with a velocity of 1200 m/s. The nozzle angle is 20°, the mean blade velocity is 400 m/s, and the inlet and outlet angles of blades are equal. The mass of steam flowing through the turbine per hour is 1000 kg. Calculate :*

(i) *Blade angles.*

(ii) *Relative velocity of steam entering the blades.*

(iii) *Tangential force on the blades.*

(iv) *Power developed.*

(v) *Blade efficiency.*

Take blade velocity co-efficient as 0.8.

Solution. Absolute velocity of steam entering the blade, $C_1 = 1200$ m/s

Nozzle blade, $\alpha = 20°$

Mean blade velocity, $C_{bl} = 400$ m/s

Inlet blade angle, θ = Outlet blade angle, ϕ

Blade velocity co-efficient, $K\left(\frac{C_{r_0}}{C_{r_1}}\right) = 0.8$

Mass of steam flowing through the turbine, $m_s = 1000$ kg/h.

Refer Fig. 8. Procedure of drawing the inlet and outlet triangles (LMS and LMN) respectively is as follows :

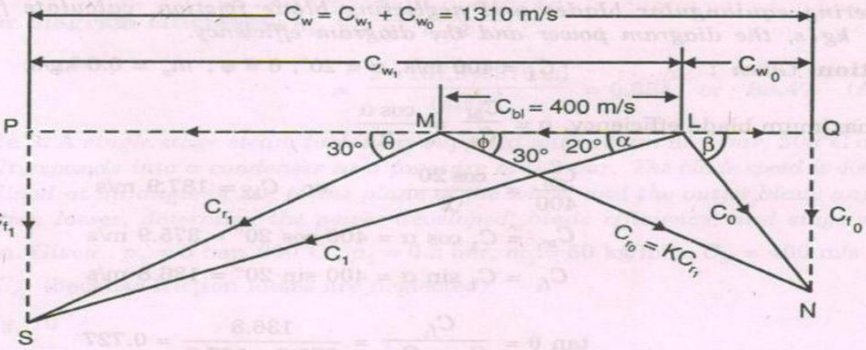


Fig. 8

- Select a suitable scale and draw line *LM* to represent C_{bl}(= 400 m/s).
- At point *L* make angle of 20° (α) and cut length *LS* to represent velocity C_1(= 1200 m/s). Join *MS*. Produce *M* to meet the perpendicular drawn from *S* at *P*. Thus *inlet triangle* is completed.

By measurement : $\theta = 30°,\ C_{r_1} = MS = 830$ m/s

$\theta = \phi = 30°$ (given)

Now, $C_{r_2} = KC_{r_1} = 0.8 \times 830 = 664$ m/s

- At point *M* make an angle of 30° (ϕ) and cut the length *MN* to represent C_{r_0} (= 664 m/s). Join *LN*. Produce *L* to meet the perpendicular drawn from *N* at *Q*. Thus *outlet triangle* is completed.

(*i*) **Blade angles θ, ϕ :**

As the blades are symmetrical (given)

$\therefore \quad \theta = \phi = 30°$. **(Ans.)**

(*ii*) **Relative velocity of steam entering the blades, C_{r_1} :**

$C_{r_1} = MS = 830$ m/s. **(Ans.)**

(*iii*) **Tangential force on the blades :**

$$\text{Tangential force} = \dot{m}_s(C_{w_1} + C_{w_0}) = \frac{1000}{60 \times 60}\ (1310) = 363.8 \text{ N.} \quad \textbf{(Ans.)}$$

(*iv*) **Power developed, P :**

$$P = \dot{m}_s(C_{w_1} + C_{w_0})\,C_{bl} = \frac{1000}{60 \times 60} \times \frac{1310 \times 400}{1000} \text{ kW} = 145.5 \text{ kW.} \quad \textbf{(Ans.)}$$

(*v*) **Blade efficiency, η_{bl} :**

$$\eta_{bl} = \frac{2C_{bl}(C_{w_1} + C_{w_0})}{C_1^2} = \frac{2 \times 400 \times 1310}{1200^2} = 72.8\%. \quad \textbf{(Ans.)}$$

Experiment No: 6

Aim: To find the condenser efficiencies.

Theory: Steam condenser is a closed space into which steam exits the turbine and is forced to give up its latent heat of vaporization. It is a necessary component of a steam power plant because of two reasons. It converts dead steam into live feed water. It lowers the cost of supply of cleaning and treating of working fluid. It is far easier to pump a liquid than a steam. It increases the efficiency of the cycle by allowing the plant to operate on largest possible temperature difference between source and sink. The steam's latent heat of condensation is passed to the water flowing through the tubes of condenser. After steam condenses, the saturated water continues to transfer heat to cooling water as it falls to the bottom of the condenser called, hot well.

Types of condenser

1. Jet condenser
2. Surface condenser

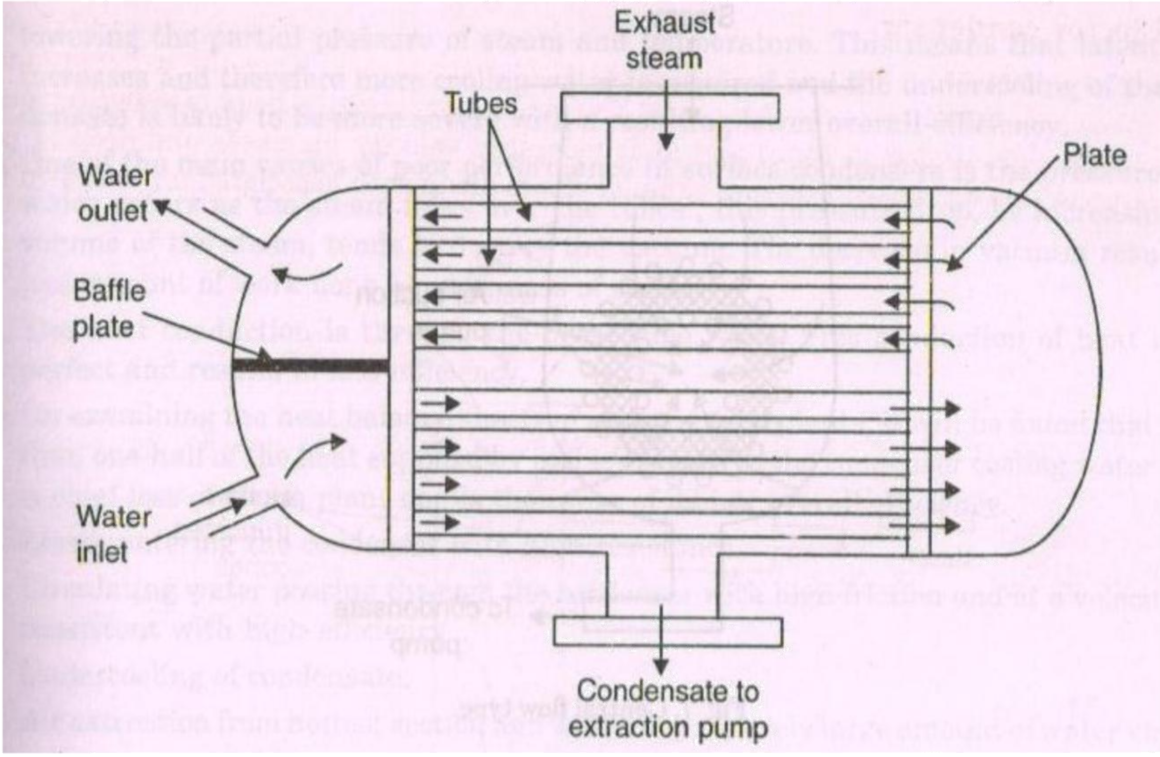
Jet condenser:-

In jet condenser the exhaust steam and water come in direct contact with each other and temperature of the condensate is same as that of cooling water leaving the condenser. The cooling water is usually sprayed into the exhaust steam to cause, rapid condensate.

Surface condenser:- In surface condenser the exhaust steam and water do not come into direct contact. The steam passes over outer surface of tubes through which a supply of cooling water is maintained. There may be single-pass or double-pass. In single pass condenser the water flow in one direction only through all the tubes, while in two-pass condenser the water flow in one direction through the tubes and returns through the remainder.

Comparison between jet and surface condenser

Jet condenser	Surface condenser
Cooling water and are mixed up.	Cooling water and steam are not mixed up.
Low manufacturing cost.	High manufacturing cost.
Require small floor area.	Require large floor space.
The condensate cannot be used as feed water in	Condensate can be reused as feed water as it
the boiler unless the cooling water is free from	does not mix with cooling water.
impurities.	It requires large quantity of cooling water.
It requires less quantity of cooling water.	More suitable for higher capacity plants.
Less suitable for higher capacity plants.	



Condenser efficiency

It is defined as the ratio of the difference between outlet and inlet temperature of cooling water to the difference between temperature corresponding to the vacuum in the condenser and inlet temperature of cooling water i.e.,

Condenser efficiency =

Numerical

The inlet cooling water temp for a surface condenser is 9°C and outlet temp is 27°C. The vacuum in the condenser is 715mm of mercury when the barometer read 760 mm. find the condenser efficiency.

Solution:

Absolute pressure = 760 – 715

= 45 mm of mercury

= $13600 \times 9.81 \times 45 \times 10^{-3}$

= 0.0612 bar

From steam table

Saturation temp corresponding to this pressure = 36.2°C

Condenser efficiency =

$= \frac{27-9}{36.2-9}$

= 66.2%

Experiment No: 7

Aim: To study cooling tower and find its efficiency.

Apparatus: Cooling Tower set up.

Theory:

Cooled water is needed for, for example, air conditioners, manufacturing processes or power generation. A cooling tower is equipment used to reduce the temperature of a water stream by extracting heat from water and emitting it to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly. Cooling towers are able to lower the water temperatures more than devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient.

Cooling towers use the evaporative cooling principle to cool the circulated water, and they can achieve water temperatures below the dry bulb temperature - t_{db} - of the air cooling air and they are in general smaller and cheaper for the same cooling loads than other cooling systems. Cooling towers are rated in terms of approach and range, where the approach is the difference in temperature between the cooled-water temperature and the entering-air wet bulb - t_{wb} –temperature the range is the temperature difference between the water inlet and exit states. Since a cooling tower is based on evaporative cooling the maximum cooling tower efficiency is limited by the wet bulb temperature -t_{wb} - of the cooling air. The water consumption - the make up water - of a cooling tower is about 0.2-0.3 liter per minute and ton of refrigeration. Compared with the use and waste of city water the water consumption can be reduced with about 90 - 95%.

There are two main types of cooling towers

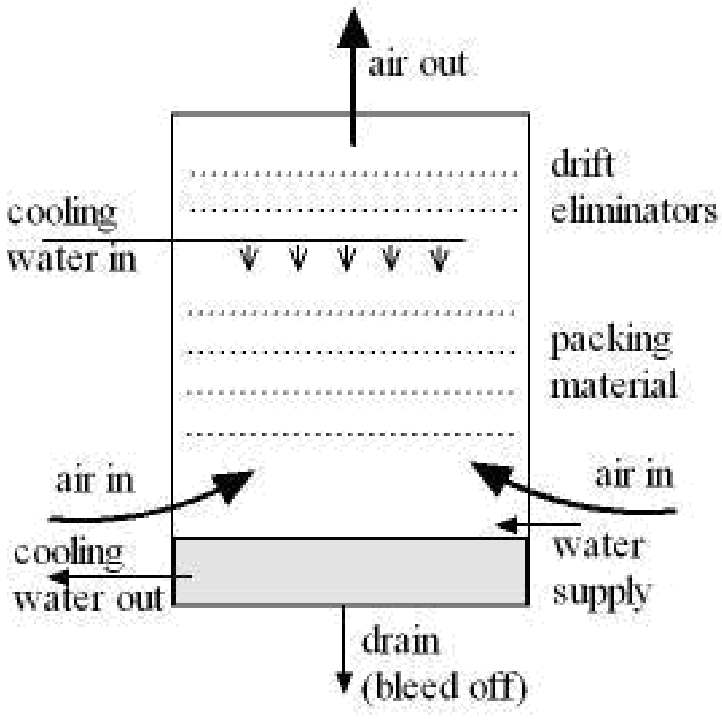
1. Natural draught
2. Artificial draught (Mechanical type)

a. Forced draught (Forced fan)

b. Induced draught (Suction fan)

Natural draught:-

When the circulation of air through the tower is by natural convection, it is known as a natural draught. In this, hot water from the condenser is pumped to top of tower where it is sprayed down through a series of spray nozzles. The hot water after giving its heat to air which circulates through the tower due to natural convection, gets cooled and is collected from bottom of tower.



rtificial draught:-
When the circulation of air through the tower is by artificial convection i. e. Forced fan, Suction fan is known as artificial draught. It is of two types:-

(a) Forced draught:-
The tower is completely encased with discharged opening at the top and fan at the bottom to produce flow of air.

(b) Induced draught:-
Here fan is placed at the top which draws air through the tower. The warm water to be cooled introduce at the top of the tower through spray nozzles. It falls through a series of trays which are arranged to keep the falling water to be broken up into fins drops. The cooled water is collected at the bottom.

Procedure:
1. Make the initial setting as per equipment.
2. Start the experiment and take the temperature readings.
3. Complete the calculations.

Observations & Calculations:

Sr. No.	T_i	T_o	T_{wb}	μ

Cooling Tower Efficiency
The cooling tower efficiency can be expressed as
$\mu = (t_i - t_o)\ 100 / (t_i - t_{wb})$ where
μ = cooling tower efficiency - common range between 70 - 75% t_i = inlet temperature of water to the tower (^oC or ^oF)
t_o = outlet temperature of water from the tower (^oC or ^oF) t_{wb} = wet bulb temperature of air (^oC or ^oF)

The temperature difference between inlet and outlet water ($t_i - t_o$) is normally in the range 10 - 15 ^oF.

Conclusion: Hence the efficiency of the cooling tower is __________.