LABORATORY MANUAL

STEAM & POWER GENERATION

ME-218-F

LIST OF THE EXPERIMENTS

SNO	NAME OF THE EXPERIMENT	PAGE NO	
		FROM	TO
1.	To study low pressure boiler and their accessories and mountings.		
2.	To study high pressure boiler and their accessories and mountings.		
3.	To prepare heat balance sheet for given boiler.		
4.	To study the working of impulse and reaction steam turbine .		
5.	To find dryness fraction of steam by separating and throttling calorimeter.		
6.	To find power out put & efficiency of a steam turbine.		
7.	To find the condenser efficiencies.		
8.	To study and find volumetric efficiency of a reciprocating air compressor.		
9.	To study cooling tower and find its efficiencies.		
10.	To find calorific value of a sample of fuel using bomb calorimeter.		
11	Calibration of Thermometers and pressure gauges.		

Note:
1. At least ten experiments are to be performed in the semester.
2. At least eight experiments should be performed from the above list. Remaining two experiments may either be performed from the above list or designed & set by the concerned institute as per the scope of the syllabus.

EXPERIMENT NO. 1

Aim:- To study low pressure boilers and their accessories and mountings.

Apparatus Used:- Model of Lancashire boiler (low pressure boiler).

Theory:- 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. As result the flow of air to the grate can be controlled.

Mountings of boiler:-There are different fittings and device which are necessary for the operation and safety of a boiler. The various mountings used on the boiler:-

1. Water level indicator:-The function of a water level indicator is to indicate the level of water in the level constantly. It is also called water gauge.
2. Pressure gauge:- The function of a pressure gauge is to measure the pressure exerted inside the vessels. It is usually constructed to indicate upto double the maximum working pressure. Its dial is graduated to read pressure in kgf/cm^2 gauge. There are two type of pressure gauges:- (i) Bourdon tube type pressure gauge
   (ii) Diaphragm tube type pressure gauge
3. Safety valves:- The function of a safety valve is to release the excess steam when the pressure of steam inside the boiler exceeds the rated pressure. The various type of safety valve is:-
   (i) Dead weight safety valve
   (ii) Spring loaded safety valve
   (iii) High steam & low water safety valve

4. Fusible plug:- The function of a fusible plug is to prevent the boiler against damage due to overheating for low water level.
5. Blow off cock:- A blow off cock or valve performs the two functions:-
    (i) It may discharge a portion of water when the boiler is in operation to blow out mud scale or sediments periodically.
    (ii) It may empty the boiler when necessary for cleaning, inspection and repair.
6. Feed check valve:- The function of a feed check valve is to control the supply of water to the boiler and to prevent the exception of water from the boiler when the pump pressure is less as pump is stopped.
7. Stop valve or Junction valve:- A junction valve is a valve which is placed directly over a boiler and connected to a steam pipe which carries steam to the engine. If a valve is placed in the steam pipe leading steam to the engine and placed near the engine. It usually termed as stop valve. The larger sizes are called Junction valve and smaller sizes Stop valve.

Accessories of boiler:- There are auxiliary plants required for steam boiler for their proper operation & for increase of their efficiency. The various accessories are:-

1. Feed pump:- The feed pump is a pump which is used to deliver feed water to the boiler . It is desirable that the quantity of water supplied should be at least equal to that evaporated and supplied to the engine. Two type of pumps which are commonly used as feed pump are :-
    (i) Reciprocating pump
    (ii) Rotary pump
2. Economiser:- An economiser is a device in which the waste heat of the flue gases is utilized for heating the feed water. Economiser is very important part of the boiler, with the help the economiser the efficiency of the boiler increased and the evaporative capacity of the boiler is increased. Economiser are of two type:-
    (i) Independent type
    (ii) Integral type
3. Air pre-heater:- The function of air preheatere is to increase the temperature of air before is enters the furnace. It is generally placed after the economiser. So that flue gases pass through the economiser and then to air preheat. Usually, there are three types of pre-heater:-
    (i) Tubular type
    (ii) Plate type
    (iii) Regenerative type
4. Super heater:- The function of a super heater is to increase the temperature of the steam above its saturation point.
5. Injector:- The function of an injector is to feed water in to the boiler. It is commonly employed for vertical and locomotive boiler and does not find its applications in large capacity high pressure boiler.

Questions for viva- voce:-

1. Explain the construction & working of various mountings of boiler?
2. Explain the construction & function of accessories of a boiler?
3. State the location and function of safety valve in a boiler?
4. State any four salient features of low pressure boiler?
5. Give the advantage of low pressure boiler?

EXPERIMENT NO. 2

Aim:- To study high pressure boilers and their accessories and mountings.
Apparatus Used:- Model of Lamont and Loeffler boiler (high pressure boiler).
Theory:- Lamont boiler:-
It is a high pressure boiler. It is water tube boiler working on forced circulation system. The water from the storage drum is drawn by the circulation pump. Compressed to about 2.5 bar above the drum pressure and supply to header which distribute water to the generating tube G. Here some water is converted into steam and a mixture of water and steam then pass into the storage drum.. The steam is further heated in the super heater before being taken out water from hot well is supplied by the feed pump through the economiser to the storage drum. The sludge if any would settle drum and can be removed from the bottom.
Loeffler boiler:- Loeffler boiler is also a high pressure water tube boiler employs the advantage of forced circulation and indirect heating. It use steam as heat carrying and heat absorbing medium before the furnace heat is only supply to economiser and super heater. The feed water from the feed pump is fed to the drum through the economiser where it gains heat from out going gases.
Mounting of high pressure boiler:-

1. Water level indicators
2. Fusible plug
3. Steam stop valve
4. Feed check valve
5. Blow off cock
6. Safety valve
7. Pressure gauge
8. Man and mud holes

Accessories of high pressure boiler:-

1. Feed pump
2. Steam injector
3. Evaporator
4. Economiser
5. Super heater
6. Air-pre heater

Evaporator:- Evaporator is used in high pressure boiler which is placed after the air in the way of flue gases water are tube. Hence evaporator is a unit which consumes the energy of flue gases in boiler. Its main function is to convert the water to steam add much to the boiler efficiency.

Questions for viva-voce:-

1. Draw a neat sketch of any one fire tube boiler?
2. State any four salient features of a high pressure boiler?
3. Classify the boiler?
4. Draw a neat sketch of any one water tube boiler?
5. Give the advantage of high pressure boiler?

EXPERIMENT NO 3

Aim:- To prepare heat balance sheet for given boiler.

Heat losses in the boiler:- The efficiency of boiler is never 100 % as only a portion of heat supplied by the fuel is utilized rest of it is lost:-

1. Heat carried away by dry product of combustion.
2. Heat carried away by the steam product by the combustion of hydrogen present in fuel.
3. Heat carried away by moisture in fuel and air.
4. Heat loss due to incomplete combustion of carbon to carbon monoxide instead of carbon dioxide and thus escape of combustable matter in the flue gases and ash.
5. Heat loss due to radiation.

Method of minimizing the heat loss:-

1. The heat loss to chimney gases may be minimized by installing an economiser in between the boiler and chimney.
2. Loss of heat may be minimized by providing the boiler with an effective draught system which will ensure sufficient supply of air through the fuel in furnace.
3. Heat loss due to unburnt fuel which may fall into ash pit may be minimized by properly sizing of coal.
4. Heat loss due to moisture content in the fuel may be minimized by making the fuel dry before charging into the boiler furnace.
5. Heat loss due to external radiation may be minimized by providing effective covering of insulating material on the boiler parts which are liable to radiate heat.

Theory:- The boiler circulation are generally based upon the high calorific value of 1 kg of fuel considered as 100 %. The term for heat balanced sheet explain earlier.

Result:- The heat balanced sheet of a boiler is studied.

1. Heat utilized by generation of steam:-
   Useful heat absorbed, $H_1 = m (h_1-h_2)$
   H_1 = Equivalent evaporation. 2256.9 KJ
2. Loss due to moisture in fuel:-
   The moisture in the fuel is evaporated and superheated and thus the heat is lost.
   Loss due to moisture in fuel, $H_2 = m_1 (n_1^1-n_2^1)$
   Where m_1 = Mass of moisture per kg of fuel of fired
   N_1^1 = Enthalpy of steam formed
   N_2^1 = Enthalpy of liquid at temperature of boiler furnace.
3. Loss due to H_2O vapour from combustion of Hydrogen:-
   This is found similarly to loss due to moisture in fuel.
4. Loss due to moisture in air:-
   This is also found in the similar way as above and it is generally negligible.
5. Loss due to dry flue gases:-
   This is the target loss that takes place inside the boiler. This is given by :-
   $H_3 = m_2C_p (t_g-t_a)$
   Where m_2= Mass of dry flue gases per kg of fuel.
   C_p= Specific heat of dry flue gases
   t_g = Temperature of flue gases
   t_a = Temperature of atmospheric (gases) air

6. Loss due to incomplete combustion of carbon:-
   This loss is caused by incomplete combustion of carbon to carbon monoxide instead of carbon dioxide. $H_4 = m_3$.CV of CO
   $H_4 = \frac{CO.C}{CO_2+CO}$. CV of CO
   C = Mass of carbon actually burned per kg of fuel
   CO & CO_2 % by volume
   CV = Number of heat unit generated by burning 1kg of carbon contained in CO to CO_2 = 23820 KJ/ Kg
7. Loss due to unconsumed combustion to refuse:-
   This loss is due to some unburnt carbon falling into the asp hit.
   $H_5 = m_4$ .CV
   m_4 = Unburnt mass of carbon in refuse per Kg of fuel
   CV = Calorific fuel of carbon.

HEAT BALANCE SHEET (Basis 1 Kg of low grade fuel)

Heat supplied (K J)	% age	Heat Expenditure (K J)	% age (in approx.)
Gross heat supplied	100	(a) Heat utilized in steam generation	78.00
		(b) Heat carried away by flue gases	12.00
		(c) Heat utilized in evaporating and superheating the moisture fuel and water vapour formed due to burning of hydrogen of fuel.	4.750
		(d) Heat loss by incomplete combustion	3.00
		(e) Heat carried away by excess air	1.500
		(f) Heat carried away by carbon nash	0.500
		(g) Heat uncounted for such as radiation and error etc.	0.250
Total	100	Total	100

Question for viva- voce:-

1. Define heat balance sheet?
2. Define the method of minimizing the heat loss in boiler?

EXPERIMENT NO 4

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, turbine 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 level" 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.

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 are 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:-

1. 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.

2. 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.

3. 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.

Questions for viva- voce:-

1. State principle of working of Reaction steam turbine?
2. Define the term stage efficiency of a turbine?
3. Define the term vacuum efficiency of a turbine?
4. What is prime mover?
5. What is compounding?

EXPERIMENT NO 5

Aim:- To find dryness fraction of steam by separating and throttling calorimeter.

Theory:- Dryness Fraction:- It is defined as the ratio of mass of dry steam actually present to the mass of wet steam which contains it is defined (denoted) by letter x.

$$x = \frac{m_s}{m_s + m_w}$$

Where m_s = mass of dry steam

m_w = mass of water or wet steam

Steam generator separating & throttling calorimeter:-

In separating & throttling calorimeter are used. The steam passing from a calorimeter may be steam containing some water particle in it. This method is basically for a wet steam. In this case it is necessary to dry the steam partially before throttling. This is done by passing the steam sample from the main through a operating calorimeter.

In separating calorimeter the steam is made to change its direction suddenly & water as heavy then steam separate out there due to inertia. The quantity of water separate out is measured, then the steam is passed through the throttling calorimeter. After that steam from calorimeter is collected and condensed & measure the condensate

$$x_2 = \frac{h_3 - h_2}{h_{fg2}}$$

Questions for viva- voce:-

1. Define the term of quality of steam?
2. What is dryness fraction?
3. What is meant by calorimeter?
4. Define the construction of separating and throttling calorimeter?
5. Define the working of separating and throttling calorimeter/

EXPERIMENT NO 6

Aim:- To find power out put & efficiency of a steam turbine.

Theory:- The velocity of steam relative of the blades, can be very easily found out by the velocity diagram.

Let,

V_b = Linear velocity of moving blade (at inlet) in m/s
V_1 = Absolute velocity of steam entering moving blades in m/s
V_{r1} = Relative velocity of steam to moving blade at inlet
V_{f1} = Axial component of moving blade
V_{w1} = Tangential component of velocity V1
α = Angle to the tangent or nozzle angle
β = Entrance angle of moving blades
V_0 = Absolute velocity of steam at outlet from the moving blade
V_{r0} = Relative velocity of steam to moving blade at exit
Θ = Angle of discharge
γ = Angle of blade at outlet
Speed ratio, $P = \frac{V_b}{V_1}$

The effective component of steam jet which produces tangential force and cause the wheel to rotate is the velocity of wheel. So the work on blade is done by this tangential force and may be find out from the change in momentum in the direction of motion. The velocity of flow is responsible for producing the axial thrust on the wheel. If there is a friction loss then

$$V_{r0} = KV_{r1}$$

Where

K is (1-friction) or (1-loss)

Otherwise

$$V_{r0} = V_{r1}$$

Width of the blade:- From the Newton second low, tangential force on the wheel is equal to (m_s .a)

$$F = m_s .a$$
m_s /s .change in velocity
$m^o_s . (V_{w1}+V_{w0})$ ---------- (1)

Because V_{w0} is already negative.

Work done by the blade / sec = (Force . Distance)/sec

Force. velocity $= F . V_b$
$= m^o_s . (V_{w1}+V_{w0}).V_b$ ---------- (2)

or = Power developed by the turbine in KW

Since the available energy of steam entering to the blades

- i.e. $m_s.V_1^2/2$ --- w/d $= \frac{m_s . (V_{w1}+V_{w0}).V_b}{m_s.V_1^2/2}$
- $\eta_b = \frac{2 (V_{w1}+V_{w0}).V_b}{V_1^2}$

- Another method to calculate η_b

$\eta_b = \frac{V_1^2 - V_0^2}{}$

V_1^2

Axial thrust on wheel:-

= mass of steam / sec. change of axial components of velocity

$= m_s \cdot (V_{f1} - V_{f0})$

If h_d is the heat drop in the nozzle ring of an impulse wheel the total energy supplied per stage is h_d per Kg of steam

Then

Stage efficiency = $\frac{\text{w/d by blade}}{\text{Total energy supplied per stage}}$

$= \frac{V_b (V_{w1} - V_{w0})}{h_d}$

If there are no losses then stage efficiency shell be same as blade efficiency

$\eta_{stage} = \eta_b \cdot \eta_{nozzle}$.

Questions for viva- voce:-

1. Differentiate between Impulse and Reaction steam turbine?
2. Define the terms of De- level turbine?
3. Define different method of Compounding?
4. Define terms axial thrust on wheel?
5. Define terms stage efficiency?

EXPERIMENT NO 7

Aim:- To find the condenser efficiencies.

Theory:- Condenser is an appliance in which steam is condensed and the and the energy given up steam in the condensing process is passed to a coolant, which is water.

It is of two types, depending upon the way in which the cooling water cools the exhaust steam.

1. Jet condenser:- In this type of condenser, the cooling water and exhaust steam come into direct contact and the temperature of condensate is the same as that of cooling water leaving the condenser. It is the three of types:-

(a) Parallel flow type:- In which both exhaust steam and cooling water outer at the top of condenser and then flow in downward direction. The condensate and water are collected from the bottom.

(b) Contra flow type:- Exhaust steam and cooling water outer from the opposite direction. Usually the exhaust steam at the bottom and rises up while the cooling water enters at the top and flow downward.

(c) Ejector type:- The mixing of exhaust steam and cooling water takes place in a series ob combining cones and K. E. of steam is utilized to assist in draining the water from the condenser into net well against the pressure of atmospheric. Parallel flow and contra flow condenser are further sub divided in two categories:-

(i) Low level type:- According to the position of condensing chamber, in case of low level type the over all height of the unit is low enough type. So that the condenser may be directly placed be near the steam turbine or engine. In this type of condenser, an extraction pump is required for drawing out the condensate, cooling water and air.

(ii) High level type :- High level condenser is similar to low level jet condenser except that it uses a barometric type or trail pipe for cooling the vacuum & removing the condensate & in some cases the non condensable gases.

2. Surface condenser:- The exhaust steam and the cooling water don't come into direct contact. The steam to be condensed is made to flow over the out side of a nest of type through which the cooling water circulates. It is following types:-

(a) Down flow type:- The steam enters at the top and flows down over the tube through which water is circulated. As the condensed steam floe perpendicular to the direction of flow of cooling water in side the tubes, this condenser is also called cross- surface condenser.

(b) Central flow type:- In the centre of the tube nest is located the suction of air extracting pump thus resulting in the flow of steam rapidly inwards. There is better contact between the outer surface of tubes and the steam due to the volute casting round the nest of the tubes.

(c) Inverted type:- The steam after entering at the bottom rises up and then again flows down following a path near the outer surface of the condenser. The condensate extraction pump is providing at the bottom while the suction pipe of the air extraction pump connected to the top.

(d) Evaporative condenser:- When the supply of cooling water is limited, its quantity required to condensate the steam may be greatly reduced by covering the circulating water to evaporative under small particle pressure due to heat capacity of gilled pipe it has the periods without seriously affecting the vacuum.

Condenser efficiency:- Condenser efficiency is defined as the ratio of the difference between the outlet and inlet temperature of cooling water to the difference between the

temperature corresponding the vacuum in the condenser and the inlet temperature of cooling water.

Condenser efficiency = Rise in temp. of cooling water

(temp. correspondence to vacuum)

- (inlet temp. of cooling water in condenser)

Questions for viva- voce:-

1. What do you mean by steam condenser?
2. What is its function?
3. Differentiate between surface and jet condenser?
4. Define the term “condenser efficiency”?
5. What are the advantages of installing a condenser in thermal power plant?
6. State the various type of steam condenser?

EXPERIMENT NO 8

Aim:- To study and find volumetric efficiency of a Reciprocating air compressor.
Also classify the air compressor (Rotary).

Theory:- This may be regarded as a machine which compresses or which is used to increase the pressure of air by reducing its volume.

Reciprocating compressor:- This is a machine which compresses air by means of piston reciprocating inside a cylinder.

Working:- It consist a piston which is enclosed within a cylinder and equipped with suction and discharge valve. The piston receives the power from the main shaft through a crank shaft and connecting rod. A fly wheel is fitted on the main shaft to ensure turning moment to be supplied throughout the cycle of operations.

Work done:-

(a) When the gas is compressed according to low.

PV^n = Constant

Work req /cycle $W = P_2V_2+(P_2V_2-P_1V_1 /n-1) – P_1V_1$

$= [(nP_2V_2-P_2V_2)+(P_2V_2-P_1V_1)-(nP_1V_1-P_1V_1)]/ n-1$

$= n (P_2V_2-P_1V_1) / n-1$

$W = P_1V_1n / n-1 (P_2V_2 / P_1V_1-1)$

$P_1V_1^n = P_2V_2^n$

$V_2 / V_1= (P_1 /P_2)^{-1/n}$

$W =P_1 V_1 n / n-1[(P_2 / V_1).(P_2 / P1)^{-1 / n} -1]$

$W = P_1 V_1 n / n-1[(P_2 / V_1)^{n-1 /n} -1]$ KJ / cycle

(b) When gas is compressed adiabatically:-

$W = P_1V_1r / r-1 [(P_2 / V_2)^{r-1 / r}-1]$ Kj / cycle

(c) When gas is compressed isothermally:-

$W = P_2V_2\log_e V_1 / V_2$ or

$P_1V_1\log_e V_1 / V_2$ KJ/ Cycle

P_1 & P_2 are in KN / m^2 & V_1 & V_2 are in m^3

Rotary compressor may be classified as:-

1. Positive displacement compressor
2. Non – positive displacement compressor

Positive displacement compressors are future classified as:-

(a) Roots blower
(b) Crescent or Vane blower
(c) Lysholm compressor
(d) Screw compressor

Non – positive compressor are classified as:-

(a) Centrifugal compressor
(b) Axial flow compressor

1. Positive displacement compressor:- It have two sets of mutually engaging cam surface or lobes. The air is trapped between the lobes and the pressure rise take place either be back blow of air from receive by squeezing action and back blow of air.
(a) Roots blower:- in which back flow of high pressure air from the receive creates rise in pressure.
(b) Vane blower:- in which combined squeezing action and back flow of air creates rise in pressure.

2. Non – positive displacement compressor: - The pressure rise in these machine is not due to space reduction or back blow action of the high pressure air from the receive as in the case of positive compressor but is due to transfer of K. E. of the fluid to the pressure energy by one or more rotating rings of curved blades known as 'Impeller'.
(a) Centrifugal compressor:- The rotating member known as the Impeller consist a large number of blades and is mounted on the compressor shaft inside stationary casting. As the impeller rotates the pressure in the region a falls and hence the air enters through the eye and flow radially outwards through the impeller blades as of the compressor. Both velocity and pressure increase as the air flow through the cylinder or impeller blades. Air enters through the convergent passage formed by the diffuse blades.
(b) Axial flow compressor:- It is more commonly used, the air flows in an axial direction right from the intake to the delivery. The working principle is illustrated in fig. The stator encloses the rotor both of which are provided with rings of blades. As the air enters in the direction it flows through the alternately arranged stator and rotor blade ring the air gets compressed successively. For efficient operation the blades are made of aerofoil section based on aero-dynamic theory. The annular area is made divergent as shown in order to keep the flow velocity constant throughout the length of compressor.

Question for viva- voce:-

1. Classify the air compressor?
2. Explain the working of Reciprocating air compressor?
3. Differentiate between Reciprocating & Centrifugal compressor?
4. Define positive displacement compressor?
5. Define non positive displacement compressor?

EXPERIMENT NO 9

Aim:- To study Cooling tower and find its efficiency.

Theory:- It is a part of power plant. In large cities where acquisition of load is very expansive, we may cooling tower for cooling purpose as they are often placed on the root of the power plant.

Function:- Its function is to increase the surface area or cool water.

Types:-

1. Natural draught

2. Artificial draught (Mechanical type)

(i) Forced draught (Forced fan)

(ii) Induced draught (Suction fan)

1. 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.

2. Artificial 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 type:-

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

(ii) 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.

Questions for viva-voce:-

1. What is the function of cooling tower in modern condensing plant?
2. State the application of cooling tower?
3. Differentiate between natural and artificial draught type cooling tower?
4. Define the term of boiler draught?
5. Give the use of cooling tower?

EXPERIMENT NO 10

Aim:- To find the calorific value of a sample of fuel using Bomb calorimeter.

Theory:- This calorimeter is used to determine the calorific value of solid and liquid fuels. The calorific value obtained by this calorimeter is the high calorific value at constant volume, because the fuel under test is went at constant volume in the closed vessel known as Bomb. The body of the bomb made of stainless steel which is capable of withstanding high pressure, heat and corrosion. It consists of a base which supports the Platinum crucible, the function of which is to contain the sample of fuel to be tested. The crucible act as conductor for the current which is used for igniting the fuel. The thread cover carries the oxygen valve for supplying oxygen and a release valve for exhaust gases.

The bomb is surrounded by a measured quantity of water contained in a container known as calorimeter. The calorimeter is future surrounded by a water jacket and an air space is provided between the two , to reduce losses of heat due to radiation. The lid of the casting is provided with suitable openings for the thermometer and stirrer. The stirrer is around the bomb and is moved up and down by means of crank and connecting rod arrangement.

Determination of calorific value of fuels by the Bomb calorimeter:-

The procedure for determine the C.V. of a non-volatile fuel is same as that of a solid fuel. A measured quantity of fuel is taken in the crucible and the ignition is effected through cotton threads which after dipping into the sample is attached to the paper disks which absorbs the liquid fuel and are then easily ignited. Thus the heat gained by water is equal to the heat given out by the sample of cotton thread or the paper disk. If the fuel under test is highly volatile, then the use of bomb calorimeter becomes dangerous because the fuel evaporates and gives out vapour which after mixing with oxygen will form an explosive mixture. Secondary, the fuel can not be measured in an open crucible without the loss in mass. In such a case the fuel is sucked in to a tired thin glass bulb by alternate heating and the cooling of the bulb, which is then sealed off and weighed. In order to break the bulb, when placed in the bomb it is encircled by cotton coated with paraffin wax, which is easily ignited. Such an arrangement is shown in fig. In may be noted that while calculating the C. V. of the fuel, due allowances is to be made for the C.V. of the wrapping.

Calorific value of the fuel:- It is defined as the number of the heat units produced by the complete combustion of a unit mass or unit volume of the fuel.

Questions for viva-voce:-

1. Define the function of Bomb calorimeter?
2. What is its used?
3. Define the construction of Bomb calorimeter?
4. Define calorific value?

CALORIFIC VALUE OF SOME ELEMENT FUEL AT N.T.P. SOLID FUELS

Fuel	Calorific value (Bomb calorimeter)	
	Higher	Lower
Anthracite	34.583	33.913
Bituminous coal	33.494	32.406
Lignite	21.646	20.390
Peat	15.910	14.486
Wood	15.826	14.319
Cock	30.731	30.480

GASOLINE FUELS

Fuel	C.V. , M J /m^3 at 15^0C atm.	
	Higher	Lower
Coal gas	20.11	17.95
Produce gas	6.06	6.02
Blast furnace gas	3.44	3.04
Natural gas	36.83	32.75
Carbon monoxide	11.84	11.84
Hydrogen gas	11.92	10.05

LIQUID FUEL

Fuel	C.V. , M J /kg (Bomb calorimeter)	
	Higher	Lower
Aviation gasoline	47.311	44.003
Motor gasoline	46.892	43.710
Vaporizing gasoline	46.055	43.210
Motor benzole	41.973	40.193
Kerosene	46.180	43.166
Diesel oil	45.971	43.166
Light fuel oil	44.799	42.077
Heavy fuel oil	43.961	41.366
Resudual fuel oil	42.054	39.961