ST.ANNE'S
COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING
V – SEMESTER (MECHANICAL)
THERMAL ENGINEERING LABORATORY – I MANUAL

NAME :________________________________
ROLL NO. :________________________________
YEAR :_______________________
BATCH :______________________________

THERMAL ENGINEERING LABORATORY
IV SEMESTER MECHANICAL ENGINEERING

1. IC ENGINES LAB AND FUELS LABORATORY

LIST OF EXPERIMENTS

1. STUDY OF IC ENGINES, COMPONENTS AND LOADING DEVICES
2. VALVE TIMING AND PORT TIMING DIAGRAMS
3. PERFORMANCE TEST ON A 4 STROKE DIESEL ENGINE
4. HEAT BALANCE TEST ON A 4 STROKE DIESEL ENGINE.
5. MORSE TEST ON MULTI CYLINDER DIESEL ENGINE.
6. RETARDATION TEST TO FIND FRICTIONAL POWER OF A DIESEL ENGINE
7. DETERMINATION OF VISCOSITY –RED WOOD VISCOMETER
8. DETERMINATION OF FLASH POINT AND FIRE POINT

2.STEAM LABORATORY

1. STUDY OF STEAM GENERATORS
2. PERFORMANCE AND ENERGY BALANCE TEST ON STEAM GENERATORS
3. PERFORMANCE AND ENERGY BALANCE TEST ON STEAM TURBINE.

EXPERIMENT 1 :

STUDY OF IC ENGINES, COMPONENTS AND LOADING DEVICES

AIM:

To identify and study the different parts of an I.C. Engine and the loading mechanisms used in it.

Apparatus required:

Cut model of an I.C. Engine.

Classifications of an I.C. Engine:

There are a number of ways by which an I.C. Engine is classified. Some of the classifications are given below:

- Based on the type of combustion as:
  Spark ignition & Compression ignition engines
- Based on the no. of power strokes per cycle as:
  4-stroke & 2-stroke engines
- Based on the mounting of the engine as:
  Horizontally mounted & Vertically mounted engines
- Based on the type cooling as:
  Air cooled & water cooled engines
- Based on the type of operation as:
  Reciprocating & Rotary Engines

Cross sectional view of a Compression Ignition Engine:

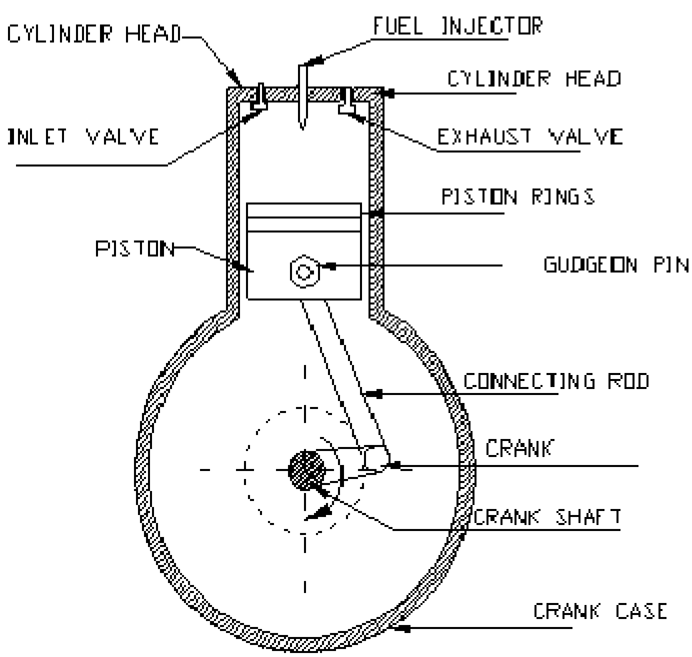


FIGURE 1

Engine Components:

Fig1 shows the cross section of an engine. The major components are listed below:

- Cylinder: It is a cylindrical sleeve in to which a close fitting piston reciprocates. The cylinder is supported by the cylinder block.

- Piston: A cylindrical component that is fitted snugly in the cylinder providing an air tight space along with the piston rings. The piston provides the combustion space inside the cylinder.

- Piston rings: These are rings that are fitted in to the slots around the piston. They provide a pressure tight seal between the piston & the cylinder wall, thus preventing the leakage of gases in to the crank case.

- Gudgeon pin: The pin that connects the piston to the connecting rod.

- Inlet Manifold: The pipe which connects the intake system to the inlet valve of the engine. It provides the passage for air fuel mixture (in SI Engines) or air alone (in C I Engines).

- Exhaust Manifold: The pipe which connects the exhaust valve of the engine to the tail pipe of the automobile. It provides the passage for the exhaust gases to be thrown out of the engine in to the atmosphere.

- Connecting rod: It interconnects the piston and the crank shaft and transmits the gas force from the piston to the crankshaft.

- Crank shaft: It converts the reciprocatory motion of the piston in to the rotary motion of the out put shaft. The crank shaft of the engine is provided with crank arms & balance weight for static & dynamic balancing.

- Inlet & Exhaust Valves: The valves used are mushroom shaped poppet type. They are provided on either side of the cylinder head for regulating the charge coming in to the cylinder and for discharging the products of combustion from the cylinder.

- Cam shaft: The shaft used to control the valve movement. It receives power from the crank shaft through a gear arrangement and a speed ratio of 1: 2 is maintained.

- Fly wheel: It is a device which is used to provide a uniform torque to the out put shaft. During the operation of an engine, the net torque produced fluctuates between a minimum and maximum value. This torque cannot be put to proper use, so in order to damn out the fluctuations; an inertia mass in the form of a fly wheel is attached to the out put shaft.

- Cooling System: During the operation of an engine, enormous heat is developed which if not properly dissipated, can lead to thermal cracks along the walls of the engine resulting in its break down. In order to dissipate this heat, the engine is provided with a cooling system. It can be classified in to air cooling & water cooling systems.

Air cooling: When the load on the engine is very less, the amount of heat produced during the operation is also less. In such cases, air cooling is preferred. Around the engine, extended surfaces called fins (as shown in Fig 2) are fixed. Due to increase in the surface area, the heat transfer rate increases resulting in higher dissipation of heat as the atmospheric air blows past the engine

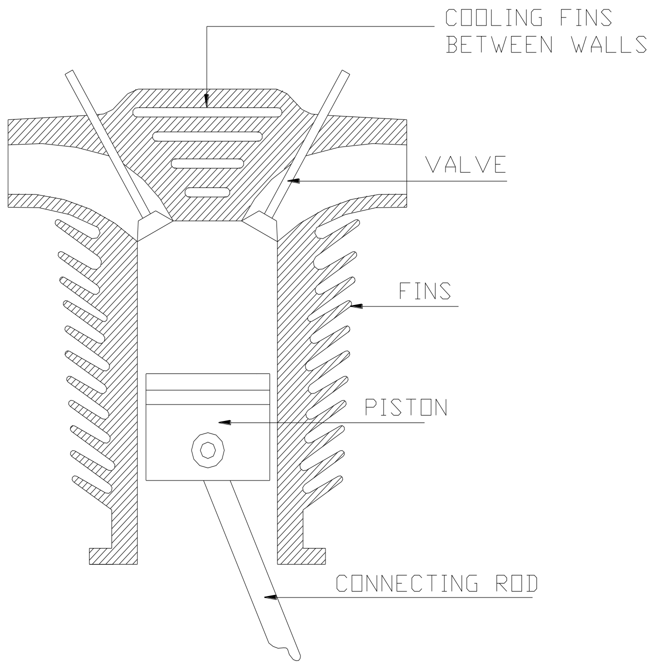


FIGURE 2

Water cooling: Air cooling can be used only in engines where the amount of heat removed is less. When a large amount of heat has to be dissipated, water cooling is always preferred to air cooling. Here water is used as the heat transfer medium. A pump is used to circulate the water around the engine through the water jackets. A heat exchanger called a radiator is used to transfer heat from the hot water to the cool air. A schematic of the water cooling system is shown in Fig 3.

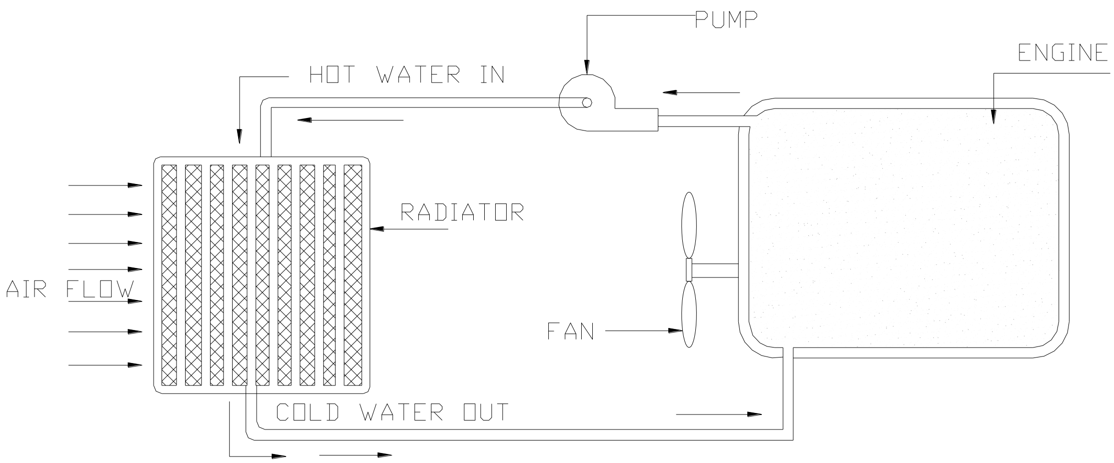


FIGURE 3

Lubrication System: An I.C, Engine has reciprocating parts in it. Due to frequent reciprocation of piston inside the cylinder, friction takes place which results in the wear and tear of engine parts. In order to prevent friction parts from getting worn out due to friction, lubricant oil is used. The system which circulates the lube oil through out the engine parts is called as lubrication system. The lubrication system can be classified as follows:

- Petroil or Mist lubrication
- Wet sump lubrication
    - Splash lubrication
    - Splash & pressure lubrication
    - Pressure lubrication
- Dry sump lubrication

A schematic of the Splash Lubrication System is shown in Fig 4.

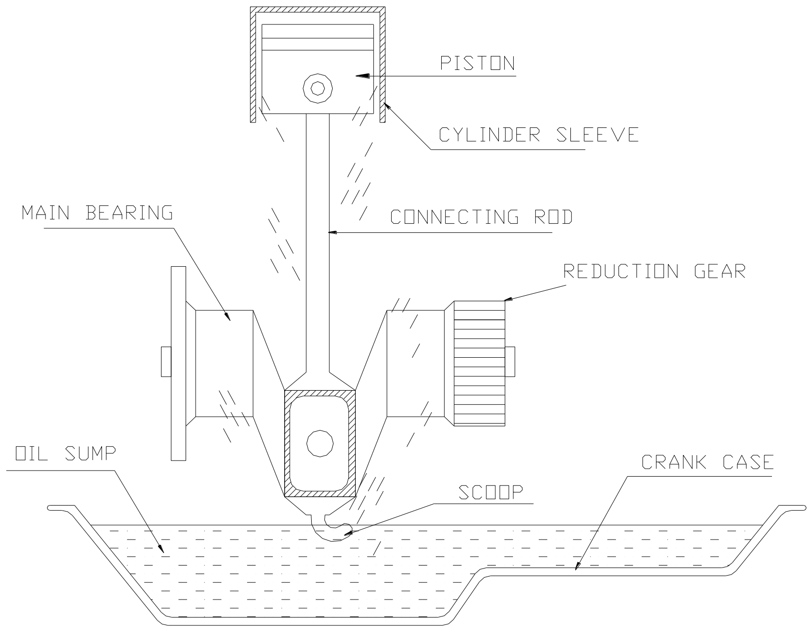


Figure : 4

General Nomenclatures used to specify an engine:

1 Cylinder bore: The nominal inner diameter of the cylinder. It is expressed in mm.

2 Stroke: The nominal distance through which a piston moves between successive reversals of its direction of motion. It is expressed in mm.

3 Piston area: The area of a circle whose diameter is equal to the cylinder bore. It is expressed in cm^2.

4 Dead Centre: The position of the piston at the moment when the direction of the piston motion is reversed at either end of the stroke. There are two dead centres:

a. Top dead centre (TDC): The dead centre when the piston is farthest from the crank shaft. It is also called Inner Dead Centre (IDC).
b. Bottom dead centre (BDC): The dead centre when the piston is nearest to the crank shaft. It is also called Outer Dead Centre (ODC).

5 Swept Volume: The nominal volume swept by the piston when traveling from one dead centre to the other. It is also called displacement. It is expressed in cubic centimeters (cc).

Swept volume $(V_s) = (\pi * d^2 * L) / 4$ cc

Where

d is the bore in cm

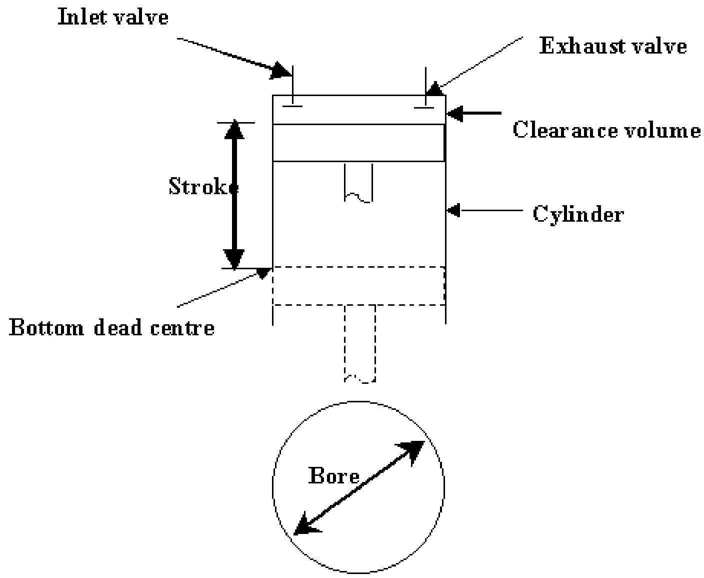
L is the stroke in cm

6 Clearance Volume (V_c): The nominal volume of the combustion chamber when the piston is at the top dead centre.

7 Compression Ratio (r): Ratio of the total volume when the piston is at BDC and the clearance volume (when the piston is at TDC).

Compression ratio (r) = $(V_s + V_c) / V_c$

TERMS RELATED WITH IC ENGINES



1.BORE

The inside diameter of the cylinder is called bore.

2.STROKE

As the piston reciprocates inside the engine cylinder,it has got limiting upper and lower positions beyond which it cannot move and reversal of motion takes place at these limiting positions.

3.TOP DEAD CENTRE(TDC)

The top most position of the piston towards the cover end side of the cylinder is called top dead centre.In case of horizontal engines, it is known as Inner Dead Centre.

4.BOTTOM DEAD CENTRE (BDC)

The lowest position of the piston towards the crank end side of the cylinder is called bottom dead centre.In case of horizontal engines, it is called the outer dead centre.

5.CLEARANCE VOLUME

The volume contained in the cylinder above the top of the piston when the piston is at top dead centre ,is called the clearance volume.

6. SWEPT VOLUME

The volume swept through by the piston is moving between top dead centre and bottom dead centre, is called swept volume or piston displacement.

7. COMPRESSION RATIO (r)

$$r = \frac{V_s + V_c}{V_c}$$

Where, V_s = swept volume, and V_c = Clearance volume

It is ratio of total cylinder volume to clearance volume.

8. PISTON SPEED

The average speed of the piston is called piston speed.

Piston speed, = 2L N

Where, L = Length of the stroke and N= Speed of the engine in rpm.

LOADING DEVICES

These devices are also known as Dynamometers, which are used to find the Torque of the engine output shaft. After the determination of the torque, and the angular speed, of the engine, the brake power can be measured .

CLASSIFICATION OF DYNAMOMETER

Dynamometers can be broadly classified as

(i)Absorption Dynamometers

These Dynamometer measure and absorb the power output of the engine to which they are coupled.The power absorbed is usually dissipated as heat by some means. Examples of such dynamometers are prony brake ,rope brake ,hydraulic ,eddy current dynamometers, etc.

(ii) Transmission Dynamometer:

In transmission dynamometers the power is transmitted to the load coupled to the engine after it is indicated on some types of scale. These are also called torque meters.

PRONY BRAKE

- This is one of the simple methods of measuring power output of an engine.
- Here ,an attempt to stop the engine by means of a mechanical brake on the flywheel and measure the weight which an arm attached to the brake will support ,as it tries to rotate with the flywheel. This system is known as the prony brake and form its use the expression brake power has come.

CONSTRUCITON

- The Prony brake consists of frames with two brake shoes gripping the flywheel.
- The pressure of the brake shoes on the fly wheel can be varied by the spring loaded using nuts on the top of the frame.
- The wooded block when pressed into contact with the rotating drum opposes the engine torque and the power is dissipated in overcoming frictional resistance.
- The power absorbed is converted into heat and hence this type of dynamometer must be cooled.
  - The brake power is given by

  BP = 2π NT

ROPE BRAKE DYNAMOMETER

- The rope brake is another simple device for measuring BP of an engine. If consists of a number of turns of rope wound around the rotating drum attached to the output shaft.
- One side of the rope is connected to a spring balance and the other to a loading device.
- The power absorbed is due to friction between the rope and the drum. The drum therefore requires cooling.
- Rope brake is quite cheaper and can be easily fabricated but not very accurate because of changes in the friction coefficient of the rope with temperature.
- The BP is given by

$BP = \pi D N (W - S)$

Where, D is the brake drum diameter

W is the Weight

S is the Spring scale reading

EXP 2 : VALVE TIMING DIAGRAM OF A 4 STROKE ENGINE

AIM: TO DRAW (i) THE VALVE TIMING DIAGRAM FOR A 4 STROKE ENGINE SHOWING THE RELATIVE CRANK ANGLES CORRESPONDING TO OPENING AND CLOSING OF INLET AND EXHAUST VALVES

APPARATUS:

CUT SECTION MODEL OF 4 STROKE ENGINE,SCALE,CHALK

FORMULA USED:

$$\text{CRANK ANGLE} = \frac{\text{Distance on Flywheel from the nearest dead centre}}{\text{Circumference of Flywheel}} \times 360^\circ$$

PROCEDURE

- The circumference of the flywheel is measured using the thread and scale.
- The flywheel is measured in clockwise direction.
- The markings corresponding to the opening and closing of inlet and exhaust valves are made on the flywheel rim.
- The distance between these markings and the nearest dead centres are measured (in cms)
- Using the above mentioned formula, the crank angle from the TDC and BDC are found and the Valve timing diagram drawn.
- Mark the valve overlap period.

TABULAR COLUMN:

VALVE OPENING /CLOSING	DISTANCE WITH RESPECT TO THE NEAREST DEAD CENTRE	CRANK ANGLE
IVO IVC EVO EVC		

RESULT

Thus, the valve timing diagram has been drawn with relative crank angle.

The angle of overlap =___________________

EXP 3:PORT TIMING DIAGRAM OF A 2 STROKE ENGINE

AIM : TO DRAW THE PORT TIMING DIAGRAM OF A TWO STROKE ENGINE.

APPARATUS : CUT SECTION MODEL OF A 2 STROKE ENGINE

PROCEDURE

- The experiment is conducted in a reduced scaled model of a 2-stroke engine. The aim is to represent diagrammatically the sequence of operation of the inlet port, transfer port and the Exhaust port.
- The flywheel of the model is rotated till the piston reaches the BDC.
- The lower most portion of the flywheel and the corresponding portion of the base is properly marked.
- The total length of the circumference of the flywheel outer rim is measured as ‘C’ corresponding to 360 degrees of flywheel rotation.
- The flywheel is rotated till the piston reaches TDC for compression stroke.
- The following points are marked on the flywheel rim:
  (i)Inlet port opening (IPO) : Fresh charge enters into the crankcase from carburetor.
  (ii) Exhaust Port Closes (EPC): After the full closing of the exhaust port and transfer port, Compression of the charge begins.
  (iii)Transfer port closes(TPC): When the reaches spark ignition accompanied by the explosion.

TABULAR COLUMN

PORT OPENING/CLOSING POSITION	DISTANCE MEASURED ALONG THE FLYWHEEL(cm)	ANGLE (Degrees)
IPO before TDC IPC after TDC EPO before BDC EPC after BDC TPO before BDC TPC after BDC		

RESULT : Hence the port timing diagram has been drawn .

EXP # 4 PERFORMANCE TEST ON SINGLE CYLINDER – 4 STROKE DIESEL ENGINE

AIM:

To conduct a performance test on the given single cylinder 4-stroke diesel engine and to draw the following characteristic curves:
a) Brake Power Vs Specific Fuel Consumption
b) Brake Power Vs Mechanical Efficiency
c) Brake Power Vs Brake Thermal Efficiency
d) Brake Power Vs Indicated Thermal Efficiency

APPARATUS REQUIRED:
Stop watch, Tachnometer

ENGINE DETAILS:
Type : Single cylinder four stroke Diesel engine Coupled to an eddy current dynamometer.
Power : 8 HP (5.9 kW)
Speed : 850 rpm.
Orifice diameter : 20 mm.
Effective radius of the brake drum : 0.2 m

PROCEDURE:

- The cooling water lines are opened.
- The fuel in the tank and the valve (used to allow fuel from tank) position are checked.
- The engine is started at no load.
- The time taken for 10 cc of fuel consumption is noted by keeping the right side knob in closed position.
- Supply of fuel from the main tank is ensured after taking the above reading.
- The manometric heights h_1 and h_2 are taken down in cm.
- The engine is loaded by adding weights on the mechanical dynamometer.
- All the above readings are noted down.
- The experiment is repeated for different current settings.
- The readings are tabulated neatly.

FORMULAE REQUIRED :

a) Brake Power (BP) = (V x I) / 1000 kW

b) Fuel consumption (FC) = $(10 \times 10^{-3} \times sp.gr. \times 3600) / t$ kg / hr

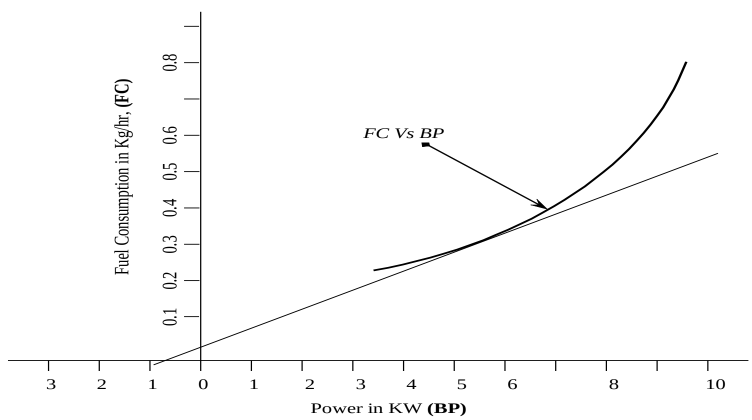
where , t - Time taken for 10 cc of fuel consumption
sp. gr. - specific gravity of diesel = 0.86

c) Specific Fuel Consumption (SFC) = FC / BP kg / kW hr

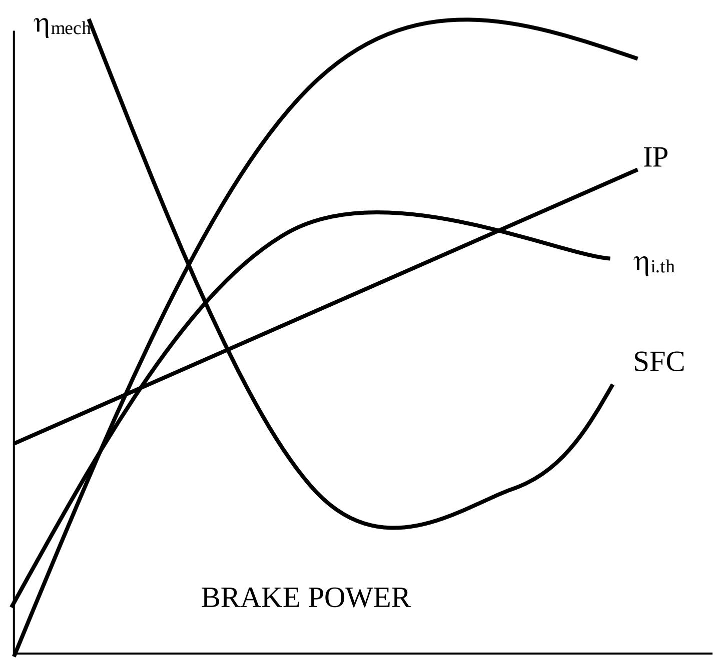
d) Heat Input (HI) = FC * CV / 3600 kJ / s
Where, CV - Calorific Value of diesel = 43500 kJ/kg

e) Brake thermal efficiency (η_{BTE}) = (BP / HI) * 100 %
f) Mechanical efficiency (η_{mech}) = (BP / IP) * 100 %
Where, BP - Brake Power, kW
IP - Indicated Power, kW = BP + FP
FP - Frictional Power, kW (To be determined from "BP Vs FC" plot)
g) Indicated thermal efficiency, : η_{ITE} = (IP / HI) x 100
RESULT:
A performance test was conducted on the given diesel engine and the following characteristic curves were drawn.
a) Brake Power Vs Specific Fuel Consumption
b) Brake Power Vs Mechanical Efficiency
c) Brake Power Vs Brake Thermal Efficiency
d) Brake Power Vs Indicated Thermal Efficiency

"WILLAN'S LINE METHOD" TO FIND FRICTIONAL POWER (MODEL GRAPH)



Frictional Power≤ 1/4th of rated power



EXPERIMENT # 5
HEAT BALANCE TEST ON 4 STROKE DIESEL ENGINE

AIM :
To conduct heat balance test on the given diesel engine and to draw up a heat balance sheet showing the proportion of useful work and various losses.

APPARATUS REQUIRED :
Stop watch, tachometer

ENGINE DETAILS:
Type : Single cylinder four stroke Diesel engine coupled to an eddy current dynamometer.
Power : 8 HP (5.9 kW)
Speed : 850 rpm.
Orifice diameter : 20 mm.
Effective radius of the brake drum : 0.2 m

PROCEDURE :

- The maximum load (full load) is calculated from the engine ratings.
- The 1/4, 1/2 and 3/4 of full load are estimated.
- The cooling water lines are opened.
- The fuel in the tank and the valve (to allow fuel from the tank) position are checked.
- The engine is started at no load condition.
- The time taken for 10 cc of fuel consumption is noted by keeping the right side knob in closed position.
- Supply of fuel from the main tank is ensured after taking the above reading.
- The following readings are also noted:
    - Temperature of cooling water outlet
    - Temperature of exhaust gas
    - Manometer readings
- The engine is loaded (with 1/4 , 1/2 , 3/4 and full load) and all the above readings are noted down.
- The readings are tabulated neatly.

FORMULAE REQUIRED :

a) Maximum load / Full load (W_{max}) = BP_{rated} x 60000 / (2π N_{rated} x R_{eff} x 9.81)
Where,
BP_{rated} - Rated Brake Power , kW
N_{rated} - Rated Speed, rpm
R_{eff} - Effective Radius of the brake drum

b) Brake Power (BP) = $2 \Pi NT/60000$ kW where ,N - speed in rpm ,T - Torque in N-m = W_{net} x R_{eff}

c) Heat carried away by cooling water (Q_{cw}) = m_w c_{pw} (t_{w2} - t_{w1})
where, m_w - mass flow rate of cooling water = $1/t_2$ kg / s
t_2 - time for 10 litres of water collection
c_{pw} - specific heat of water = 4.187 kJ / kg K
t_{w1} - temperature of cooling water at inlet , ^{o} C
t_{w2} - temperature of cooling water at outlet, ^{o} C

d) Heat carried away by exhaust gases (Q_{eg})
= $m_g c_{pg}$ (t_{go} - t_{gi})
where,
m_g - mass flow rate of exhaust gases = $m_f + m_a$
m_f - mass flow rate of fuel = 10 x 10^{-3} x sp.gr / t_1
sp. gr. - specific gravity of diesel = 0.86
t_1 - time taken for 10 cc of fuel consumption
m_a- mass flow rate of air = $\rho_a C_d$ A_o $\sqrt{2g\,h_a}$
where, C_d - Co efficient of discharge of orifice meter = 0.62
A_o - Area of orifice meter = π d^2 / 4
d - diameter of orifice
g - 9.81 m/s^2
h_a = (h_1 - h_2)* ρ_w / (ρ_a * 100)
where,
h_1 h_2 - manometer readings cm
ρ_w - density of water = 1000 kg / m^3
ρ_a - density of air at room temperature
= (ρ_a at STP) * 273 / (273+t_R)
where,
ρ_a at STP = 1.18 kg / m^3
t_R - Room Temperature , ^{o} C
c_{pg} - specific heat of exhaust gases = 1.005 kJ / kg K
t_{go} - temperature of exhaust gases , ^{o} C
t_{gi} - temperature of atmospheric air, ^{o} C

e) Heat Input (HI) = m_f x C.V.
where, m_f - mass flow rate of fuel , kg / s
C.V. - Calorific Value of diesel = 40,500 kJ / kg

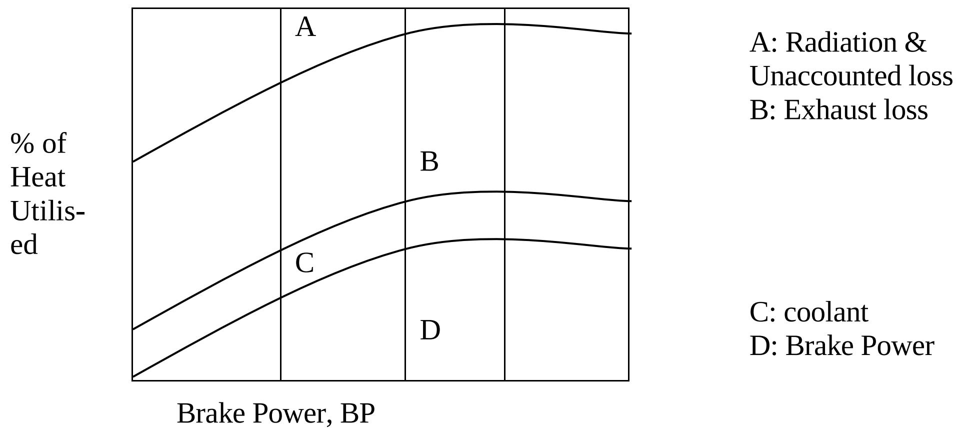
f) Unaccounted Heat loss (Q_{un}) = HI - (BP + Q_{cw} + Q_{eg}) kJ / s

GRAPH:

Brake power(x axis) Vs Thermal Energy distribution. (Y axis)

Heat input (x axis) Vs Thermal Energy Distribution (Y axis)

RESULT: A heat balance test was conducted on the given diesel engine and a heat balance sheet has been drawn up for different load conditions.


A
B
C
D
% of
Heat
Utilis-
ed
Brake Power, BP
A: Radiation &
Unaccounted loss
B: Exhaust loss
C: coolant
D: Brake Power

EXPERIMENT # 6

MORSE TEST ON A 4 CYLINDER DIESEL ENGINE COUPLED WITH HYDRAULIC DYNAMOMETER

AIM : To conduct a morse test on a multicylinder engine coupled with hydraulic dynamometer and to find the frictional power.

SPECIFICATIONS:

1. Number of cylinders = 4.
2. Power = 7.36 kW / 10HP
3. Speed = 1500 rpm
4. Type = 4 Cylinder 4 stroke vertical- Diesel engine
5. MAKE = Ambassador
6. Loading = Hydraulic Dynamometer

APPARATUS REQUIRED:

1. Dynamometer.
2. Tachometer.

DEFINITIONS:

1. Brake Power(BP): The net power available at the output shaft of the internal combustion engine is called brake power. It is the power available after some power is utilized for overcoming friction.
2. Indicated Power(IP): The horse power developed inside the cylinder is called Indicated Power.
3. Friction Power(FP): The difference between indicated power and brake power is called Friction Power.
4. Mechanical Efficiency: The ratio of brake power to the indicated power expressed as a percentage is called Mechanical Efficiency.

CALCULATION OF THE MAXIMUM LOAD THAT CAN BE APPLIED TO THE ENGINE :

BP_{rated} = (W_{max} x N_{rated}) / 2720

W_{max} = 7.36 x 2720 /1500 = 13.35 kg

Bp_{rated} = 7.36 kW

N_{rated} = 1500 rpm

W_{max} is in kg

FORMULAE:

1. Brake Power(BP_T) = (W x N)/ 2720 kW
   where, W = Load applied in kg,
   N = Speed in rpm,
   2720 = Dynamometer constant.
2. Total Indicated Power (IP_T) = [IP_1 + IP_2 + IP_3 + IP_4] kW
   where, 1 – I cylinder is cut off.
   2 - II cylinder is cut off.
   3 - III cylinder is cut off.
   4 - IV cylinder is cut off.
3. If ,BP : Brake Power developed when all the cylinders are working, then
   IP_1 = BP – BP_1.
   IP_2 = BP – BP_2.

$IP_3 = BP – BP_3$.

$IP_4 = BP – BP_4$.

4. $BP_1 = W_1 \times N / 2720$

BP_1 : Brake power of the engine when the first cylinder is cut off .

BP_2 : Brake power of the engine when the second cylinder is cut off.

BP_3: Brake power of the engine when the third cylinder is cut off.

BP_4: Brake power of the engine when the fourth cylinder is cut off.

W_1:Load on the dynamometer when the first cylinder if cut off and the speed is maintained to be N rpm.

5. Mechanical Efficiency = $(BP_T/IP_T)*100\%$.

PROCEDURE:

1. The engine is first started by checking the fuel, lubricating oil, cooling water etc., with all 4 cylinders working.
2. The speed of the engine is adjusted to a particular value say 1500 rpm and the BP of the engine at that speed is calculated.
3. Now cylinder 1 is cut-off and the speed is adjusted to 1500 rpm byn decreasing the load and the BP is found out.
4. The difference of BP of all the 4 cylinders and that of the cut off cylinder gives the IP of the cylinder of the cut-off cylinder.
5. In this way each cylinder is cut-off and the BP is found out.
6. From the value of BP the IP of all the cylinders is found out.
7. The sum of the indicated powers of all the cylinders gives the indicated power of the entire engine.
8. The Mechanical Efficiency is then calculated at that particular speed.

CONDITIONS	LOAD	BRAKE POWER B.P=[(W x N)/2720] kW	INDICATED POWER	MECHANICAL EFFICIENCY
	W kg	kW	Watts	%
SPEED , N, (rpm)	USUALLY , 1200 RPM , 1300 RPM, OR 1500 RPM			
All cylinders working				
First cylinder is cut off				
Second cylinder is cut off				
Third cylinder is cut off				
Fourth cylinder is cut off				

RESULT:

Thus the Morse Test on the 4-stroke, 4-cylinder diesel engine is carried out and the mechanical efficiency is determined.

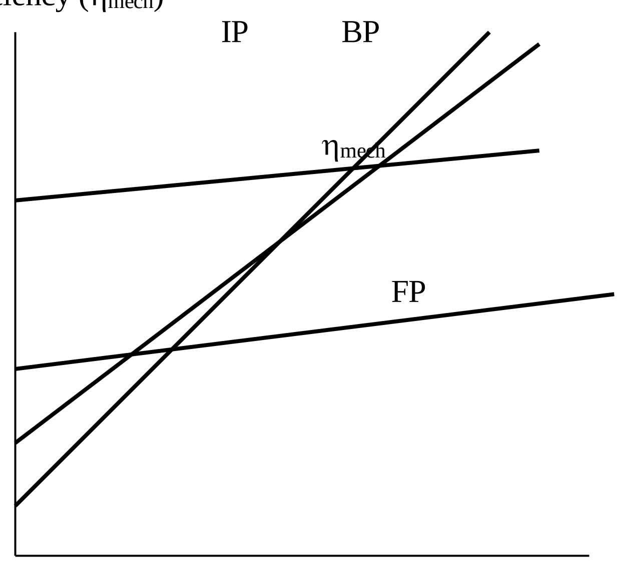
PRECAUTION

1.Lubricating oil level should be checked.
2.Cooling water should be supplied to engine and dynamometer.
3.Water is to be supplied to dynamometer and water pressure is to be 0.5 kg/cm^2.

GRAPH :

SPEED

(i) vs Brake Power (BP)
(ii)vs Indicated power (IP)
(iii)Frictional power (FP)
(iv)Mechanical Efficiency (η_{mech})



EXPERIMENT # 7: RETARDATION TEST TO FIND THE FRICTIONAL POWER OF A 4 - STROKE DIESEL ENGINE

AIM:

To conduct the retardation test on the given single cylinder 4-stroke diesel engine and to draw the graph between the Drop in speed and the time taken.

APPARATUS REQUIRED:
Stop watch, Tachometer

ENGINE DETAILS:
Type : Single cylinder four stroke Slow speed Diesel engine,
Loaded with a brake drum dynamometer.
Power : 8 HP (5.9 kW)
Speed : 850 rpm

PROCEDURE:

- The cooling water lines are opened.
- The fuel in the tank and the valve (used to allow fuel from tank) position are checked.
- The engine is started at no load and allowed to run at the rated speed for about 5 minutes..
- After the engine has attained the rated speed, the fuel supply is cut off. The time taken for the speed to decrease through 100 rpm from the rated speed is noted.
- As soon as the reading is taken, the fuel is again allowed to flow and the maximum speed is reached to achieve
- Time for 200 , 300 and 400 rpm drop of speed from the maximum speed is taken.
- The engine is now loaded to 50% of the full load and is allowed to attain the rated speed.
- After attaining the rated speed, the same procedure is followed and the time for the various speed reductions is noted.
- The readings are tabulated neatly.

Calculation of the Maximum load , Wmax

- Brake Power (BP) = $(2\pi N_{rated} T)/(60 \times 1000)$ kW
- Brake Torque (T) = $(BP \times 60000) / (2\pi N_{rated})$ Nm.

$$=(5.9 \times 60 \times 1000)/(2 \pi \times 850)$$

$$T = 66.32 \text{ Nm}$$

$T = W_{max} \times R_{eff}$

$W_{max} = T / R_{eff}$

$=66.32 / 0.2 = 331.58 \text{ N} = 331.58 / g = 331.58 / 9.81 = 33.8 \text{ kg}$

Hence the maximum load that can be applied to the engine is 33.8 kg.

R_{eff} = Effective radius of the brake drum = 0.2 m

FORMULAE USED FOR CALCULATIONS :

- Brake Power (BP) = $(2\pi NT)/(60 \times 1000)$ kW

N: Speed values of the engine from the tabular column.

T : Brake torque = $W_{net} \times R_{eff}$.

$W_{net} = W_1 + w - W_2$.

W_1:Load added on the weight hanger.

w: Weight of the hanger. = 2 kg

W_2:Spring balance reading, kg

- Torque at ½ load ($T_{1/2}$) = T / 2 Nm = 66.32 /2 = 33.16 Nm

- Frictional que(T_f) = $(T_{1/2} * t_1) / (t_2 - t_1)$

  Where t_i is the time for a drop of 100 rpm at no load

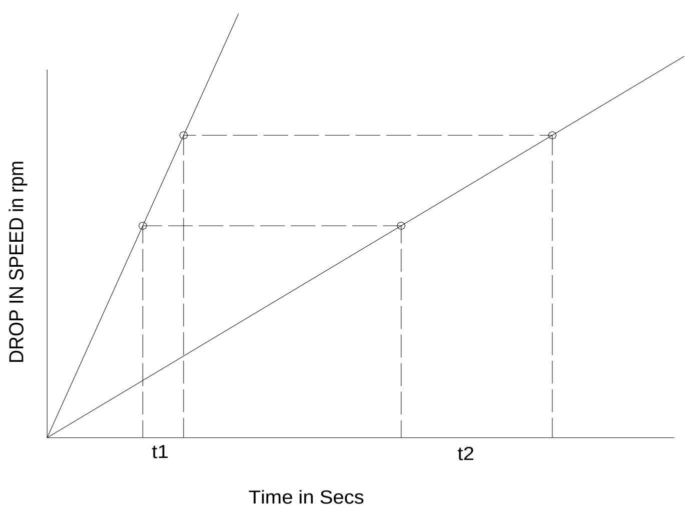
  t_2 is the time taken for a drop of 100 rpm at 50% load.

- Frictional Power (FP) = $2\Pi NT_f / 60000$.

TABULAR COLUMN :

S. No.	Speed Variation “rpm”	Drop in speed N “rpm”	Time for the speed drop at no load t_1 , sec	Time for the speed drop at 50% load t_2,sec
1	715 – 615			
2	715 - 515			
3	715- 415			
4	715- 315			

MODEL GRAPH :



RESULT:

Thus the retardation test on the single cylinder 4- Stroke diesel engine was conducted and the frictional power was found to be _________________

EXPERIMENT # 8

DETERMINATION OF VISCOSITY USING REDWOOD VISCOMETER

AIM

To determine the viscosity of the given oil at various temperatures and study the variation of viscosity with temperature.

APPARATUS REQUIRED

Thermometer and stop watch

DESCRIPTION

- The given apparatus consists of two metal cups with holes at the bottom.
- The oil in the cup receives heat from the surrounding water which in turn is heated by a coil.
- Provisions are made to measure the temperatures of water and oil.
- To ensure uniform heating an electric stirring arrangement is provided.

PROCEDURE

- The oil cup is cleaned and the oil is poured.
- Sufficient water is poured in the space surrounding the cup.
- The time taken for collection of 60 ml of oil is noted at room temp.
- The heater and stirrer are switched on.
- The time taken for collection of 60 ml of oil is noted at different temperatures from 40º C to 60º C with an interval of 10º C.
- The values of kinematic and absolute(dynamic) viscosities are calculated using Redwood seconds.

FORMULAE REQUIRED

1. Kinematic Viscositym, $\nu = [A t - B / t]$ stokes where,
A = 0.0026 & B = 1.88
2. Density $\rho = \rho_r - 0.000657 (T - T_r)$ kg / lt
where, ρ_r - density at room temperature = 0.84 kg / lt
T - temperature at which viscosity is determined T_r - room temperature

3. Absolute viscosity or dynamic viscosity $\mu = \nu * \rho$ poise

note:
1 stoke = $1 cm^2 / s$; 10 poise = $1 N s / m^2$

TABULAR COLUMN

Sl.No.	temp. of water	temp. of oil	time for 60ml of oil collection	density	kinematic viscosity	absolute or dynamic viscosity
	^{o} C	^{o} C	sec	kg / lt	stokes or cm^2 /s	Poise

RESULT

The viscosity of the given oil was found out at various temperatures and following graphs were plotted.

a) temperature Vs density
b) temperature Vs kinematic viscosity
c) temperature Vs absolute viscosity
d)Temp Vs Redwood Seconds

EXPERIMENT # 8

DETERMINATION OF FLASH & FIRE POINT OF LIQUID FUEL

AIM:

To determine the flash and fire points of the given oil using Pensky-Mortein's apparatus.

APPARATUS REQUIRED:

Thermometer

Flash and Fire points:

Flash point is the temperature to which the oil must be heated to give off sufficient vapour to form an inflammable mixture with air.

Fire point is the lowest temperature at which the production of combustible gas from the oil is enough to maintain a steady flame after ignition.

DESCRIPTION:

- The apparatus consists of a brass cup with a filling mark inside.
- The cup is surrounded by electric heating elements.
- The brass cup is closed with a cover where provisions are made to insert thermometer,to introduce test flame and to connect the stirrer.

PROCEDURE:

- The oil cup is cleaned and dried.
- The oil is poured in the cup up to the filling mark.
- The flash and fire points are noted in the open conditions.
- The cup is covered with the given lid.
- The heater is connected to the mains and the rate of heating is adjusted.
- As the oil temperature increases, the test flame is applied at an interval of 20^{o}C to find the flash and fire points.

TABULAR COLUMN:

sample oil	condition	Sl.No.	Flash point	Fire point
	open cup	1 2		
	closed cup	1 2		

RESULT:

a) The flash point of the oil

1) in open condition is _________ ºC

2) in closed condition is _________ ºC

b) The fire point of the oil

1) in open condition is _________ ºC

2) in closed condition is _________ ºC

STEAM LABORATORY

EXPERIMENT # 1
STUDY OF STEAM BOILER AND TURBINES

AIM : To study and understand the principle of steam boilers and turbines.

THEORY:
DEFINITION:
Boiler, also called steam generator is the engineering device which generates steam at constant pressure .It is a closed vessel, generally made of steel in which vaporization of water takes place.
Heat required for vaporization may be provided by the combustion of fuel in furnace ,electricity ,nuclear reactor, hot exhaust gases, solar radiations. etc.

TYPES OF BOILERS:
Boilers are of many types. Depending upon their features they can be classified as given under:
(a)Based upon the orientation /axis of the shell.
(i)Vertical boiler has a vertical shell..
(ii)Horizontal boiler has its shell horizontal.
(iii)Inclined boiler has its shell inclined .

(b)Based upon utility of boiler.
(i)Stationary boiler
(ii)Portable boiler

(c)Based on the type of firing employed.
(i)externally fired boiler; e.g : Lancahsire boiler, Locomotive boiler
(ii)Internally fired boiler ., e.g .Cochran boiler, Babcock and Wilcox boiler

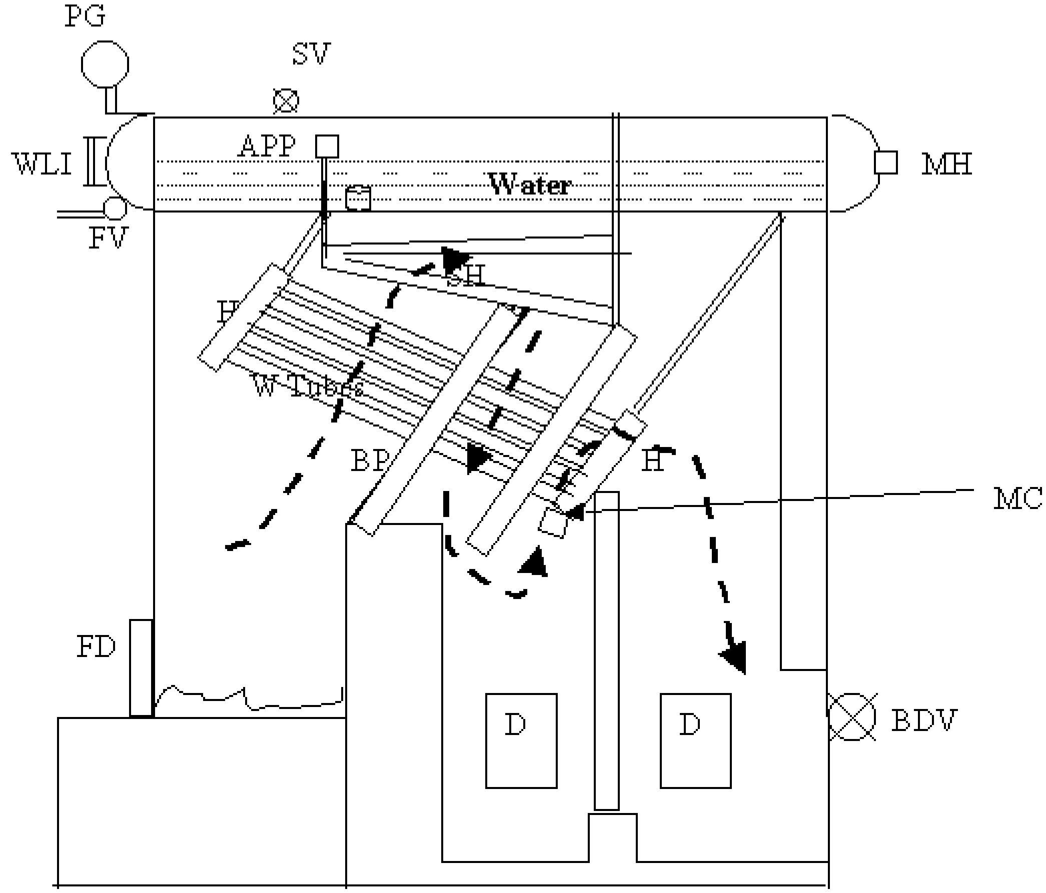
(d)Based on the tube content.
(i)Fire tube boiler e.g : Cornish, Cochran, Lancashire, Locomotive boiler.
Hot gases flow through the tubes and water surrounds them.
(ii)Water tube boiler
Water flows through the tubes and hot gases surrounds them.
e.g : Babcock and Wilcox boiler, Stirling boiler, La- Mont boiler, Benson boiler .

(e)Based on the type of fuel used.
(i)solid fuel boiler :e.g : coal fired boilers.
(ii)Liquid Fuel boiler , e.g: Oil fired boilers.
(iii)Gas fired boiler : e.g: Natural gas fired boilers.

(f)Based on circulation
According to the flow of the water/steam is caused by the density difference which is due to the temperature variation.
(i)Natural circulation
Here, the circulation of water/steam is caused by the density difference which is due to the steam temperature.
(ii)Forced Circulation boilers.
Here, the circulation of water /steam is caused by a pump, or fan.

One Water tube boiler is discussed below.

BABCOCK AND WILCOX BOILER :



SV : Safety valve
MH :Man hole
PG :Pressure Gauge
BP :Baffle Plate
WLI: Water Level Indicator
APP :Anti priming pipe
SH :Super heater
H :Header
D: Door
BDV: Blow down valve
WT: Water Tubes
FV: Feed Valve
MC: Mud collector
FD :Fire Door
G :Grate

Definition

Babcock and Wilcox boiler is an example of water tube boiler which is horizontal straight tube boiler and may be designed for stationary or marine purposes.

The particulars relating to this boiler are

Diameter of the drum	1.22 to 1.83 m
Length	6.096 to 9.144 m
Size of the water tubes	7.62 to 10.16 cm
Size of the super heater tubes	3.84 to 5.71 cm
Working pressure	40 bar (max)
Steaming capacity	40000 kg/hr (max)
Efficiency	60 to 80 %

The Babcock and Wilcox Boiler consist of a drum connected to a series of front end and rear end header by short riser tubes. To these headers are connected a series of inclined water tubes of solid drawn mild steel.

The angle of inclination of the water tubes to the horizontal is about 15° or more. A hand hole is provided in the header in front of each tube fro cleaning and inspection of tubes. A feed valve is provided to fill the drum and inclined tubes with water the level of which is indicated by the water level indicator. Through the fire door the fuel is supplied to grate where it is burnt.
The water form the drum flows through the inclined tubes via down take header and goes back into the shell in the form of water and steam via uptake header. The steam gets collected in the steam space of the drum. The steam then enters through the anti-priming pipe and flows in the super-heater tubes where it is further heated and is finally taken out through stop valve and supplied to the engine when needed. At the lowest point of the boiler is provided the mud collector to remove the mud particles through a blow down clock.

BOILER MOUNTINGS

1.WATER LEVEL INDICATOR

It is used for knowing the level of water in the boiler.

2.SAFETY VALVE

Its function is to prevent the steam pressure from exceeding a limiting maximum pressure value. Safety valve should operate automatically by releasing excess steam and bring pressure down within safe limits.

3.FUSIBLE PLUG

It is a safety device used for preventing the level of water from going down below a critical point and thus avoid overheating. It is mounted at crown plate of combustion chamber.

4.PRESSURE GAUGE

It is mounted at front top. Pressure is continuously monitored so as to avoid occurrence of over shooting of boiler pressure.

5.STOP VALVE

It regulates the flow of steam from the boiler .This is generally mounted on highest part of boiler shell and performs function of regulating the flow of steam from boiler.

6.FEED CHECK VALVE

It is a non return valve at the end of delivery pipe from feed water pump and is placed on boiler shell slightly below normal water level. It is used to fill the boiler with water.

7.BLOW OFF COCK

It is used for cleaning by discharging the water and sediments from bottom of boiler. Blow off cock also helps in regulating the salt concentration as frequent draining helps in throwing out salt deposited over period of time. Opening blow off cock removes deposited sediments in boiler.

8.MANHOLE AND MUD BOX

Manhole provides the opening for cleaning ,inspection and maintenance purpose.
Mud box is a collection chamber for collecting the mud.

ACCESSORIES

1.SUPER HEATER

Its purpose is to super heat steam and is a type of heat exchanger in which steam flows inside tubes and hot gases surround it.

2.ECONOMISER

An economizer is a device used to heat feed water by utilizing the heat in the exhaust flue gases before leaving through the chimney.

3.AIR PREHEATER

An air preheater is used to recover the heat from the exhaust flue gases. It is installed between the economizer an the chimney. The air required for the purpose of combustion is drawn through the air preheater where its temperature is raised. It is then passed through the ducts to the furnace. The air is passed through the tubes of the heater internally while hot flue gases are passed over the outside of the tubes.

<u>STEAM TURBINES</u>

A steam turbine is a prime mover in which rotary motion is obtained by the gradual change of momentum of the steam.
In general a steam turbine consists of the following
1.The nozzle in which the heat energy of high pressure steam is converted to kinetic energy ,so that the steam issues from the nozzle with a very high velocity.
2.The blades change the direction of steam issuing form the nozzle, so that a force acts on the blades due to the change of momentum and propel them.

PRINCIPLE

The principle of steam turbine is the generation of high velocity steam jet by the expansion of high pressure steam and then conversion of kinetic energy , so obtained into mechanical work on rotor blades.

CLASSIFICATION OF STEAM TURBINE

1.According to the mode of steam action
(i)Impulse turbine (ii)Reaction turbine

2.According to the direction of steam flow
(i)Axial flow turbine (ii)Radial flow turbine

3.According to the exhaust condition of steam (i)Condensing turbine (ii)Non condensing turbine

4.According to the pressure of steam
(i)High pressure turbine   (ii)Medium Pressure turbine (iii)high pressure turbine

5.According to the number of stages
(i)Single stage turbine   (ii)Multi stage turbine

IMPULSE TURBINE

An impulse turbine is a turbine which runs by the impulse of steam jet of this turbine, the steam is first made to flow through the nozzle. Then the steam jet impinges on the turbine blades (which are curves like blades) and are mounted on the circumference of the wheel. The steam jet after impinging glides over the concave surface of the blades and finally leave the turbine.

REACTION TURBINE

In a reaction turbine, the steam enters the wheel under pressure and flows over the blades.The steam, while gliding ,propels the blades and make them to move.As a matter of fact, the turbine runner is rotated by the reactive forces of steam jets.The backward motion of the blades is similar to the recoil of a gun.

DIFFERENCE BETWEEN THE STEAM AND TURBINE AND A STEAM ENGINE

Sr No	Criteria	Steam Turbine	Steam Engine
1	Thermal Efficiency	High	Less
2	Balancing	As there is no reciprocating parts in steam turbine, perfect balancing is possible.	Hard to achieve perfect balancing and needs heavy foundation.
3	Speed	Higher and greater range of speed is possible	Lesser range of speed.
4	Lubrication	simple	Complicated
5	Need of Flywheel	As the power generation here is at a uniform rate, a flywheel is not required.	A flywheel is needed.
6	Steam consumption	Less	More
7	Compactness	More compact	Bulky
8	Construction	Lighter construction and easier maintenance	Complex construction
9	Cost	Affordable cost than the steam engine	Costly than the steam turbine.

RESULT : Hence , the steam generator and the steam turbine are studied.

EXPERIMENT #2
PERFORMANCE AND ENERGY BALANCE TEST ON A STEAM GENERATOR

AIM : To conduct a test on an oil fired steam generator and

(i) To Calculate the Boiler Thermal Efficiency
(ii) To Draw the heat balance test.

SPECIFICATIONS :
TYPE : Non IBR – Automatic , three pass, Oil fired Boiler with Economiser.
CAPACITY : 200 Kg/hr
OPERATING PRESSURE : 12 kg/cm^2.
FUEL : High Speed Diesel
CALORIFIC VALUE : 44500 kJ /kg

APPARATUS :
Steam generator Test Rig, and accessories.

PRECAUTIONS
1.Check the water level in the feed water tank.
2.Check the fuel level in the diesel tank.
3.Switch on the mains.
4.Switch on the side switch , and check the panel./
5.Start the water pump after opening the blow down valve.
6.Wait for two minutes.
7.Ensure that water flow is there and close the blow down valve.
8.Start the burner.
9.Allow the pressure to rise to $10kg/cm^2$ in the boiler.
10.Close the steam valve to build the pressure.
11.The steam bypass valve is opened to enable the steam to be exhausted to the turbine, maintaining the pressure.

The following observations are recorded in the observation table.(TABLE #1)
OBSERVATIONS :
1.Clock time (in minutes)
2.Steam pressure , p
3.Dryness fraction , x = 0.9 (assumed)
4.Initial and final level of water in the feed water tank, W_{h1} and W_{h2}.
5.Temperature of feed water , T_w.
6.Initial and final level of fuel in the Diesel feed tank, D_{h1} an D_{h2}.
7.Flue gas temperature , T_g.
8.Room temperature , T_R.
9.Air flow meter manometer differential reading ΔA_h , in mm.
10.Repeat the above measurements three times every ten minutes.

TABULAR COLUMN

OBSERVATION TABLE :

TIME	Steam Pr	Feed Water Tank Level		Feed Water Temp.	Oil level in Diesel Tank		Flue Gas Temp	Room Temp	Manometer reading	
t	P	Initial Wh1	Final Wh2	Tw	Initial Dh1	Final Dh2	Tg	T_R	Initial Ah1	Final Ah2
MIN	Kg/cm^2	cm	cm	°C	cm	cm	°C	°C	cm	cm

FORMULAE AND CALCULATIONS: (for performance test)

1.TOTAL DURATION OF TEST , t_d.

$t_d = (t_4 – t_1)$ minutes.

2.AVERAGE STEAM PRESSURE , p_{avg}.

$$p_{avg} = \left[\frac{p_1 + p_2 + p_3 + p_4}{4} \right] \text{ kg/cm}^2.$$

3.ABSOLUTE STEAM PRESSURE , P.

P= 0.9807 X (p_{avg} + 1.032) kg/cm^2.

4.AVERAGE FEED WATER TEMPERATURE , Tw.

$$Tw = \left[\frac{T_{W1} + T_{W2} + T_{W3} + T_{W4}}{4} \right] °C$$

5.AVERAGE ROOM TEMPERATURE , T_R. $_R$ = $\left[\frac{T_{R1} + T_{R2} + T_{R3} + T_{R4}}{4} \right]$ °C

6.AVERAGE FLUE GAS TEMPERATURE , Tg

$$Tg = \left[\frac{T_{g1} + T_{g2} + T_{g3} + T_{g4}}{4} \right] °C$$

7.MASS OF STEAM GENERATED BY THE BOILER IN ONE HOUR , m_s.

m_s = Fall in water level in td minutes x Area of feed water tank (m^2) x 1000 x $\frac{60}{t_d}$

$$= \frac{\Delta Wh}{1000} \times (1.252 \times 0.602) \times 1000 \times \frac{60}{t_d} \quad \text{kg /hr}$$

Here ,

ΔW_h = (Final level – Initial level) in water tank in mm.
Area of feed water tank = (1.252 x 0.602) m^2.

8.Mass of fuel oil supplied in one hour, m_f.

m_f = Fall in fuel level in td minutes x Area of fuel tank (m^2) x 950 x $\frac{60}{t_d}$

where ,
ΔD_h =(Final level – Initial level) in fuel tank in mm.
Area of fuel oil tank =(0.4 x 0.4) mm^2.

(a) Enthalpy, ,h of steam generated at pressure , p
$h = h_f + h_{fg}$, for dry saturated steam , kJ /kg
$h = h_f + x\, h_{fg}$, for wet steam
where x = 0.9 (assumed)
h_f and h_{fg} , are read from steam tables for absolute steam pressure , P .

(b) Enthalpy , h_w of water at feed water temperature, T_w.
h_w is read from steam tables for T_w in kJ /kg.

10.BOILER THERMAL EFFICIENCY , η_{THERM}

$$\eta_{THERM} = \frac{ms(h - hw)}{mf \times 44500} \times 100 \quad \%$$

RESULT :
Hence the Boiler performance test has been conducted and the efficiency is found out to be ______________________%.

CALCULATIONS FOR ENERGY BALANCE TEST OF STEAM GENERATOR

1.MASS OF AIR SUPPLIED IN ONE HOUR, m_a.

$$m_a = 1.23 \times 0.62 \times 0.00785 \times \left(2 \times g \times 814 \times \frac{\Sigma \Delta A_h}{4} \right)^{0.5} \times 3600$$

$$m_a = 1362.5 \times \left(\Sigma \Delta A_h \right)^{0.5} kg/hr$$

$$\Sigma \Delta A_h = \Delta A_{h1} + \Delta A_{h2} + \Delta A_{h3} + \Delta A_{h4}$$

ΔA_h is the water level difference in manometer.

Density of Air = 1.23 kg/m3.

Coefficient of orifice = 0.62

Diameter of orifice = 0.1 m

Area of orifice = 0.00785 m^3.

Water to air density ratio = 814

2.HEAT GAINED BY THE STEAM FROM THE BOILER PER HOUR, (Q_S).

$Q_S = m_S$ X $(h-h_W)$ Kj/hr

3.EVAPORATION RATE , m

$$m = \frac{m_s}{m_f}$$ kg steam / kg fuel

4.EQUIVALENT EVAPORATION , m_e :

$$m_e = m_s \times \frac{h - h_w}{2260}$$ kg/hr

2260 : Latent heat of steam at 1 bar

5.HEAT GENERATED BY BURNT FUEL OIL , Q_f :

$Q_f = m_f$ x CV kJ /hr

CV : Calorific Value of fuel oil = 44500 kJ /kg

6.HEAT LOST TO FLUE GAS , Q_g:

Q_g =mg x C_{pg} x ($T_g - T_R$)

mg = (m_a +m_f) kg

8.HEAT BALANCE SHEET

a) HEAT INPUT , Qf

b)useful heat, Qs =

c)Heat in exhaust gas , Qg =

d) Radiation and other unaccounted losses , Qun =

HEAT BALANCE SHEET ON HOUR BASIS :

HEAT SUPPLIED	kJ	Heat utilization , kJ	%
	Qf = mf x CV	Heat used to generate steam Qs=	(Qs/Qf) x 100
HEAT SUPPLIED BY FUEL		Heat carried by dry flue gases , Qg =	(Qg/Qf) x 100
		Heat unaccounted for , Qun=	(Qun x Qf) x 100

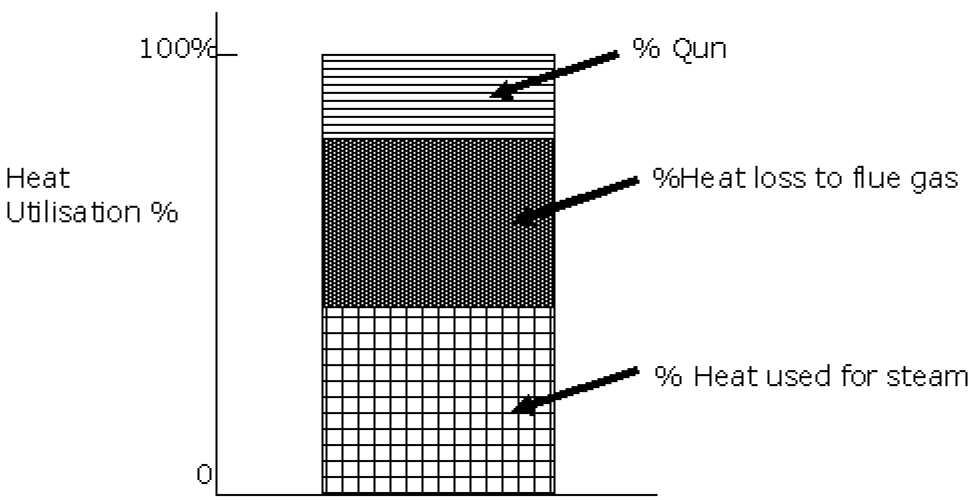
GRAPH :

A Graph is drawn between heat balance in % of heat input and % of heat utilized.

% QunEXPERIMENT # 1

STUDY OF STEAM BOILER AND TURBINESEXPERIMENT #2

PERFORMANCE AND ENERGY BALANCE TEST ON A STEAM GENERATOR



RESULT: Hence A test is conducted on the boiler and the equivalent evaporation capacity and its thermal efficiency are determined.Also a heat balance sheet is drawn.

EXPERIMENT #3

PERFORMANCE AND ENERGY BALANCE TEST ON A STEAM TURBINE

AIM : To conduct a test on the impulse steam turbine and to draw the performance curves and draw a heat balance sheet.

SPECIFICATION :
TURBINE: IMPULSE
NO. OF NOZZLES : 3
INLET PRESSURE : 10 kg/ cm^2.
STEAM FLOW RATE : 0.01 kg/ s / Nozzle
SPEED OF TURBINE : 3000 RPM

STARTING AND RUNNING PROCEDURE :
1.Start the boiler and maintain a pressure of 10 kg/ cm^2.
2.Switch on the steam turbine panel which is connected to a 3 phase 440 V power source with neutral connection.
3.Swtich on the vacuum reciprocating pump.
4.Mainitch on the turbine panel board is switched on.When sufficient pressure (10 kg/ cm^2 to 12 kg/ cm^2) is built in the boiler, allow cooling water to circulate through the condenser by switching on the condenser water supply pump.Slowly open the boiler main valve a little and simultaneously open the main line valve's bypass valve in the steam line and the ball valve provided under the turbine.
5.When all the condensed water in the steam line and the turbine is driven out close the main line bypass valve and the valve under the turbine.
6.Adjust the handle of dynamometer spring balance screw so that the balance is just loaded to 0 kg.
7.Open the steam valve and adjust so that a pressure of 10kg/cm^2 , is maintained on the turbine pressure gauge.
8.When the turbine speed reaches about 2000rpm, load the turbine by switching on the individual switches to the bulbs.
9.Enter the observations.
10.Switch on another bulb on the loading device and after few minutes note down all the observations.
11.While doing the experiment control the pressure so that the turbine inlet pressure remains at 10 kg/ cm^2 and the sufficient water is in the boiler.

Turbine Speed	Steam Pr		Steam Temp		Time Taken For 4 cm rise in condensate tank	Spring balance reading	Cooling Water		TSC	Turbine Output Power	Cooling Water Flow meter Mano Meter Reading		
	In let	Out let	In let	Ou tlet			In let	Out let			Hm1	Hm2	ΔHm
n	P1	P2	T1	T2	tc	W_D							
rpm	Kg/cm^2												

CALCULATIONS :

1.Converstion of kg/ cm^2 to bar.

=[0.9807 x { p_1 (kg/cm^2) + 1.032 }] bar

p1 : Steam pressure at turbine inlet.

2.Total steam consumption , TSC.

TSC + (1271 / tc) kg/ hr

tc : Time taken for 4 cm rise in water level of condensate tank in sec.

3.Specific Steam consumtion , SSC

SSC = TSC / Pd kg/ kW

Pd : Turbine Output power

$$P_d = \frac{1.294 \times n \times W_D}{10000} kW$$

n : Speed of the turbine in rpm.

W_D: Dynamometer spring balance reading , kg.

4.Rankine Efficiency , η_{RE}:

$$\eta_{RE} = \frac{(T_1 - T_2)\left(1 + \frac{h_{fg1}}{T_2}\right) - T_2 \ln\left(\frac{T_1}{T_2}\right)}{(T_1 - T_2) + h_{fg2}}$$

T_1 : Temperature of steam at turbine inlet in °C
T_2 : Temperature of steam at turbine outlet in °C
h_{fg1} : Enthalpy of vaporization from saturated steam tables for T_1 °C
h_{fg2} : Enthalpy of vaporization from saturated steam tables for T_2°C

5.Rankine Engine Efficiency , η_{REE}.

$$\eta_{REE} = \frac{h_1 - h_2}{h_1 - h_{f2}} \times 100 \quad \%$$

h1 = hf1 + x1 hfg1
S1 = S2 = Sf1 + x1 sfg11 = sf2 + x2 Sfg2
Sf2 and sfg2 are found from sat steam tables for T_2 °C.
Find x2
h2 = hf2 + x2 hfg2

hf2 and hfg2 are found for T2 °C

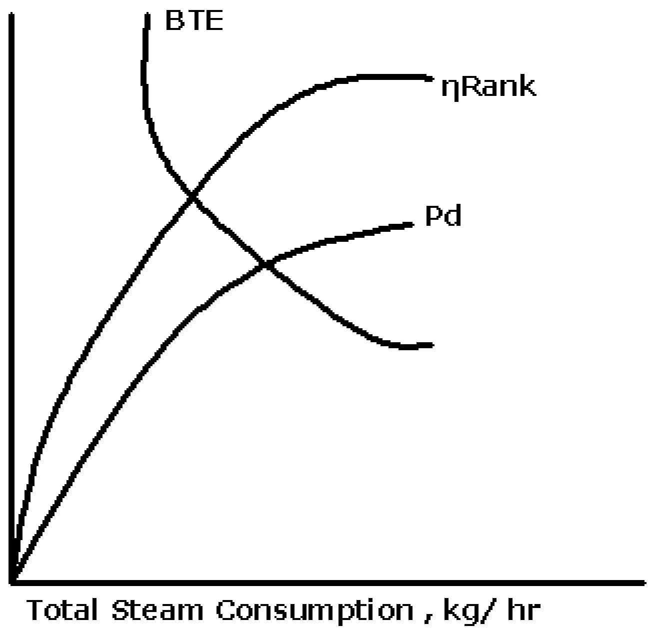
6. Brake Thermal Efficiency , BTE in %

$$BTE = \frac{Pd \times 100 \times 3600}{TSC(h_1 - h_2)}$$

7.Relative Efficiency = (BTE / RE) x 100 %

calculations table :

St Pr.	St Pr	TSC	Turbine Output Power	SSc	Rankine Eff	Rank. Engine Eff.	BTE	Rel Eff.
inlet	Outlet		Pd		ηRE	ηREE		ηRel
P1	P2							
bar	bar	Kg/hr	kW	Kg/ kW hr	%	%	%	%



GRAPHS :

1.TSC Vs TURBINE O/P POWER

2.TSC Vs RANKINE EFFICIENCY

3.TSC Vs BRAKE THERMAL EFFICIENCY

HEAT BALANCE CALCULATIONS :
1.HEAT INPUT AT TURBINE INLET , Qi

Qi = TSC X h_1 kJ /s

2.HEAT CARRIED AWAY BY CONDENSATE , Qc
Qc = TSC X hfc .
Hfc : Enthalpy of condensate liquid for Tc °C

3.HEAT EQUIVALENT OF WORK DONE , Pd , kJ / s

4.HEAT CARRIED AWAY BY CONDENSOR COOLING WATER .

$$Qw = m_c (h_{fo} - h_{fi})$$

m_c = Cooling water mass flow rate measured from flow meter manometer in kg/ s.

$$m_c = K_M \sqrt{\Delta H_m} \quad \text{kg / s}$$

ΔHm = cooling water flow meter manometer reading in mm.
$K_M = 2.081 \times 10^{-3}$ constant
h_{fi} : Enthalpy of water at inlet temperature of cooling wateer, T_{w1} °C
h_{fo} : Enthalpy of water at outlet temperature of cooling wateer, T_{w2} °C

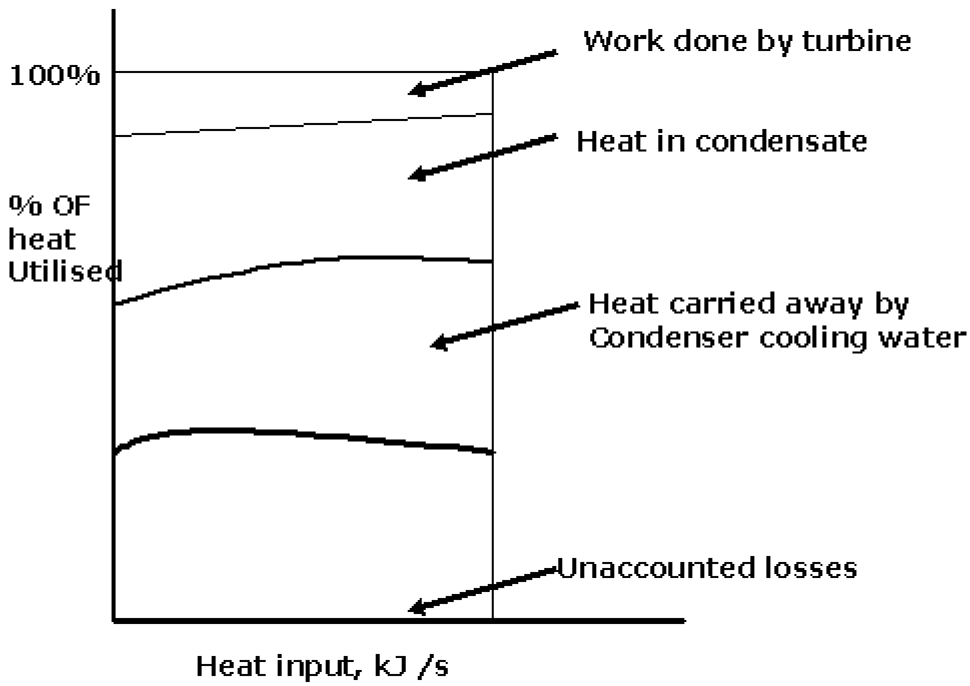
5.Unaccounted losses, Qun = 1 – (2+3+4) kJ /s
All the above are calculated for each of the 4 or 5 sets of readings.

1	2	3	4	5	6	7	8	9	10
n	Qi	Qd	Qc	Qw	Qun	Refer below (11)	Refer below (12)	Refer below (13)	Refer below (14)
rpm	kJ/s	kJ/s	kJ/s	kJ/s	kJ/s	%	%	%	%

1.Turbine Speed
2.Heat input at turbine inlet
3.Heat Equivalent of work done
4.Heat carried away by condensate
5.Heat carried away by condensate cooling water
6.Unaccounted losses , Qun
7.% of heat used , = (Qd / Qi) x 100
8.% of heat carried away by condensate , (Qc / Qi) x 100
9.% of heat carried away by condenser cooling water ,
(Qw / Qi) x 100

10.% of unaccounted heat loss (Qun / Qi) x 100
11. (Qd / Qi) x 100
12. (Qc / Qi) x 100
13. (Qw / Qi) x 100
14. (Qun / Qi) x 100

HEAT BALANCE SHEET



Result : Hence the performance of the steam turbine has been worked out and the graphs drawn .The heat balance sheet has also been drawn.