M J C E T

Mechanical Engineering Department

Thermodymics Laboratory Manual

Prepared by Dr. ASREDDY

LIST OF EXPERIMENTS

Subject: **THERMODYNAMICS LAB** Course code: ME 331

Thermodynamics lab (ME-331)

Scheme of Syllabi for BE III year – Mechanical, Semester-I

Instruction	**3 periods per week**
Duration of University Examination	**3 hours**
Sessionals	**25 Marks**
University Examination	**50 Marks.**

S.No.	Name of the Experiment
1.	To determine volumetric efficiency, isothermal efficiency and mass flow rate if a two stage reciprocating air compressor.
2.	To determine valve/port timing diagram of a Petrol/Diesel engine.
3.	To conduct performance test on single cylinder Diesel engine.
4.	To conduct heat balance test on a Diesel engine.
5.	To conduct Morse test on multi cylinder Petrol engine.
6.	To conduct performance test on multi cylinder Petrol engine.
7.	To conduct performance test on two-stroke Petrol engine.
8.	To conduct performance test on multi cylinder Diesel engine.
9.	To study the performance of a Petrol engine under different compression ratios
10.	Exhaust gas analysis of Diesel engine for carbon-monoxide and unburnt hydrocarbons
11.	Exhaust gas analysis of Diesel engine for carbon deposits using smoke meter.
12.	Determination of viscosity of lubricating oil.
13.	Determination of flash and fire points of a Fuel
14	Study of IC engine parts by using cut section models
15	Study of boilers by using models

Laboratory Safety Rules and Precautions

- The laboratory time table must be strictly followed, and the students must be punctual for their session.
- Clothing should be appropriate for working in the laboratory. Ideally, dress for lab should include long pants and shoes which cover the entire foot.
- Carefully follow the instructions of the lab instructor and course coordinator.
- Please check wiring connections before switching on the power.
- Keep flammable and combustible materials away from open flames.
- Handle toxic or exhaust gases only under the directions of the lab instructor.
- Students should never disturb the original computer configuration or setup: BIOS setup, Windows Operating System setup, Files and directory created, etc.
- Unauthorized copying of software, or using illegally copied software is strictly forbidden.
- Please turn off heater after use.
- Ensure that all gas valves are turned off.
- Keep insoluble waste material out of the sink.
- Report immediately to the laboratory Instructor if any injury occurred.

In case of emergency, please evacuate as soon as possible.

EXPERIMENT-1

PENSKY MARTIN'S APPARATUS

Aim: To determine the flash and fire point of the lubricating oils by conducting open and close cup tests.

Apparatus: Pen sky Martin's apparatus with heating coil and set of thermometers.

Introduction: Engine oils are generally formulated oils. They consist of mineral, semi- or fully synthetic base oil (base stocks) plus a varying number and amount of additives. The quality of engine oil depends on the base stock and its properties as well as on the additives. The main requirements for engine oil are defined temperature-viscosity properties, protection against wear and corrosion, keeping the engine clean, holding particles like soot or abrasives in suspension, yield strength under compression and many more. Engine oils are available in different SAE grades to suit the climate where it is used and the purpose of the user

Definitions:

Flash Point: Flash point is the lowest temperature at which oil when heated gives off sufficient vapors which form an explosive mixture in the air that ignites momentarily when exposed to flame or spark. The fire point is one measure of the tendency of the test specimen to support combustion.

The flash point is one measure of the tendency of the lubricating oil to form a flammable mixture with air under controlled laboratory conditions. It is only one of a number of properties that should be considered in assessing the overall flammability hazard of a material.

Flash point value is used in storage, transportation, shipping and safety regulations to define flammable and combustible materials. Flash point can indicate the possible presence of highly volatile and flammable materials in a relatively nonvolatile or nonflammable material. The results of this test method may be used as elements of a fire risk assessment.

Fire Point: Fire point id the lowest temperature at which oil when heated produces a vapour-air mixture that burns continuously once it is ignited

Open Test: In this test the oil is heated in a vessel with upper surface of oil exposed to the atmospheric conditions. The temperature of the lubricant is gradually raised and an ignition source is passed over the top of it, until it reaches a point at which it "flashes" and ignites.

Close Test: Closed Cup Flash point is conducted inside a closed vessel which is not open to the outside atmosphere. The lid is closed and the ignition source is introduced into the vessel itself, allowing for a closer approximation to real-life conditions (such as those found inside a fuel tank).

The close cup arrangements generally produce lower flash points, since the heat is contained and the oil is more likely to become flammable at an earlier stage. Because of this, they are generally used as industry standards, because they deliver lower results, which ensure safer practices.

Description: The oil in the brass cup having a capacity of 60 cc is electrically heated and the temperature is controlled by a dimmer stat. Heating of oil is done at the rate of about 5-6 ^{o}C rise per minute. At first the flash point is determined and the oil is further heated until at a temperature the vapour continues to burn in atmosphere this temperature is noted as fire point.

Fig. Pensky Martin Apparatus

Fig.Pensky Martin Apparatus

Procedure:

1. Fill the cup with the oil to be tested up to the filling mark. Place it in the apparatus. Fix the open clip. Insert the thermometer of high or low range as per requirement.

2. Light the test flame and introduce the flame over the oil cup. Flash point is taken as that temperature when a flash first appears at any point on the surface of the oil in the cup. Take care that the bluish halo that sometimes surrounds the test flame is not confused with the true flash. The flash point should be taken as the temperature read on the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup.

3. After flash point, heating should be continued at such a rate that the increase in temperature recorded by the thermometer is in the range of 5°C - 6°C per minute. The fire point should be taken as the temperature read on the thermometer at which the application of test flame causes the material to ignite and burn for at least 5 seconds

Observations:

Ambient Temperature = °C

Open Cup Test

S. No	Name of the Oil	Flash Point °C	Fire Point °C
1	SAE-		
2	SAE-		

Closed Cup Test

S. No	Name of the Oil	Flash Point °C	Fire Point °C
1	SAE-		
2	SAE-		

Typical values

S. No	Name of the Oil	Flash Point °C
1	Servo-SAE 20W-40	200
2	Servo-SAE 15W-40	205
3	Servo-SAE 20W-50	210

Reference information: Single grade oil like 15W or SAE 40 oil has a high viscosity when cold and a lower viscosity when hot. The first number 15W is the viscosity of the oil at cold temperature, and the second number 40 is the viscosity at 100 °C

The 15W40 designation means that the oil is multigrade oil. It has the viscosity of 15W when cold and the viscosity of SAE 40 when hot. This means that one type of oil works in all temperatures.15W40 means that at cold temperatures the oil has the same viscosity as SAE 15W oil (The numbers from 0 to 25 have the letter W added. This means that they are "winter" viscosity for use at lower temperatures) At high temperatures it has the same viscosity as SAE 40 oil.

Performance benefits of Lubricating Oils:

Enhanced engine life, Ensures increased engine cleanliness ,Maximum power output, Superior performance in terms of oxidation stability, Excellent wear protection at high temperatures and severe operating conditions, Outstanding overall engine cleanliness, Enhanced engine life, Higher fuel efficiency, Easier cold starting and excellent all weather performance due to improved cold weather properties and should be Catalytic Converter compatible.

Results:

EXPERIMENT-2

ABEL'S APPARATUS

Aim: To determine the Flash and Fire point of the fuels/light oils using Abel's Apparatus.

Apparatus: Abel's Apparatus with electrical heating unit and a set of thermometers.

Definitions:

Flash Point: Flash point is defined as the lowest temperature at which oil gives off sufficient vapours which form an explosive mixture in the air, which ignites momentarily when exposed to flame.

fig:Abel's apparatus

Description: Abel's apparatus is used to determine the flash point of light oils and fuels. Fuel Oil is heated indirectly by a hot water bath which surrounds the oil cup. A thermometer shows the temperature of oil and water separately. Test flame is taken near the oil bath frequently to determine the flash point.

Observation at Ambient Temperature:

S.NO	Name of the Fuel	Flash Point ^{0}**C**
1	Kerosene	
2	Diesel	

Fuel/lubricant	Density in Kg/m^3
Petrol	730-740
Diesel	830-840
Kerosene	790-820
LPG –Liquid / vapour at 15 ^{0}C	.55-.58 / 2.21
Natural gas	0.7- 0.9
Lubricating Oils	880-940
Water at 4 ^{0}C	1000

LPG is a mixture of commercial butane and commercial propane. LPG vapour is heavier than air, it would normally settle down at ground level/ low lying places, and accumulate in depressions.

Typical Properties						
SAE Grade	20	30	40	50	90	140
Kinematic viscosity @40^{0}C, cSt	68	90	148	200	220	340
Kinematic viscosity @100^{0}C, cSt	8.5	10.5	14.5	18	18.5	24
Pour Point ^{0}C	-26	-23	-20	-20	-20	-2
Flash Point ^{0}C	210	210	210	213	213	213
Fire Point ^{0}C	225	225	230	240	240	250

Results :

EXPERIMENT-3

REDWOOD VISCOMETER

Aim: Determination of Absolute and Kinematic viscosity of the given lubricating oil at different temperatures by Redwood Viscometer

Apparatus: Redwood Viscometer, Kohlrausch Flask, stop watch, hydrometer, thermometer. diameter of orifice = 1.9 mm.

Principle:

Viscosity is the property of a fluid that determines its resistance to flow. It is an indicator of flow ability of a lubricating oil; the lowest the viscosity, greater the flow ability. It is mainly due to the forces of cohesion between the molecules of lubricating oil.

Absolute Viscosity may be defined as "the tangential force per unit area which is required to maintain a unit velocity gradient between two parallel layers. It is denoted by µ. Its Unit in CGS system is poise and its dimensions are $ML^{-1}T^{-1}$ (1 poise = 1 dyne s/cm^2 = 1 g/(cm s) = (1/10) Pa s = (1/10)N s/m^2)

Kinematic viscosity is traditionally measured by noting the time taken for a fluid sample to travel through an orifice in a capillary under the force of gravity. The time taken is noted and converted into Kinematic Viscosity, reported in Centistokes units (cSt).

Kinematic viscosity is the ratio of - absolute (or dynamic) viscosity to density

Kinematic Viscosity (cSt) =Dynamic Viscosity (cP) / Fluid Density (kg/m3)

In the SI-system the theoretical unit of kinematic viscosity is m^2/s - or **Stoke (St)** where 1 St (Stokes) = 10^{-4} m^2/s = 1 cm^2/s. (1 St = 100 cSt and 1 cSt (Centistokes) = 10^{-6} m^2/s = 1 mm^2/s)

Effect of temperature on Viscosity

Viscosity of lubricating oil is inversely proportional to the temperature i.e. with increase of temperature, viscosity decreases. This is due to the decrease in intermolecular attraction. At higher temperature, oil must have sufficient viscosity to carry loads. Hence heavier oils are used at higher temperature. Similarly, light oils are used at low ambient temperature.

Effect of pressure on Viscosity

Lubricating oils are subjected to extreme pressure at the inter phase between gears and rolling element. At such higher pressure, viscosity of lubricating oil increases considerably. Viscosity helps in selecting good lubricating oil

Light oils Heavy Oils

Having low density High density, Easy flow ability Low flow ability, Used for; High speed, low pressure Used for; Low speed, high pressure, & Low temperature & high temperature

Significance of Viscosity measurements

Viscosity is the property of lubricating oil that determines it ability to lubricate and through its film strength, viscosity values are used. In evaluating load carrying capacity In denoting the effect of temperature changes and for determining the presence of contaminants in used oil during service. Absolute viscosity values are required for use in all bearing design calculations and other lubrication engineering technical design problems.

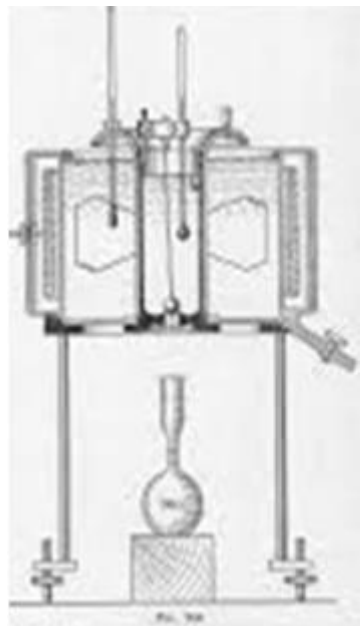


FIG: Redwood viscometer

FIG: Kohlrausch Flask

Relevant Formulae:

Kinematic Viscosity (ν) = (At – B/t) cm^2/s. (St)

Where A = constant of viscometer = 0.0026 cm^2/s^2.

B = constant of viscometer = 1.72 cm^2.

Absolute Viscosity(μ) = (Kinematic Viscosity x Density)

= (At-B/t) x ρ gm/cm-s

Where ρ is the density of the oil measured in gm/cm^3

Measurement of viscosity of lubricating oil

The instrument used for measuring the viscosity is known as viscometer.

Different types of viscometers are

1. Redwood Viscometer 2. Say bolt Viscometer

Both the above viscometers are identical in principle, shape and mode of testing. The redwood viscometer is used by British and Say bolts viscometer is used in USA. If the flow of an oil through the Redwood viscometer at 20^0C is 100 Seconds, then its viscosity is called as 100 “Redwood seconds” at 20^0C . Redwood viscometer 1 is used for Redwood seconds less than 2000 and Redwood viscometer 2 for Redwood seconds greater than 2000

Description of the Redwood viscometer

1. Oil Cup; This apparatus has silver plated oil cup of , Height-90mm, Diamtere-46.5mm, which has a concave opening at the bottom The valve at the bottom of the cup consists of a ball with a silver coated wire which can be lifted to open the valve (orifice of specified dimension)

2. Water Bath: Oil cup is surrounded by water bath for adjusting the temperature

3. Kohlrausch Flask: It receives the oil from polished-agate discharge tube Redwood viscometer

Dimensions of orifice Length-10mm, Dia-1,8mm. Kohlrausch flask Smaller mouth Wider mouth Useful for Low viscous oil having flow time between 30s-2000s e.g. Kerosene oil and mustard oil Higher viscous oils having flow time greater than 2000s e.g. Fuel oil, mobile oil

4. Thermometers**:**. Thermometers are inserted in water and oil baths to record temperature separately. A uniform temperature distribution can be achieved by stirring the oil.

Procedure:

1. Clean the viscometer cup properly with the help of suitable solvent e.g. CCl4, ether, petroleum spirit or benzene and dry it to remove any traces of solvent.
2. Level the viscometer with the help of leveling screws.
3. Fill the outer bath with water for determining the viscosity at 80^0C and below.
4. Place the ball valve on the jet to close it and pour the test oil into the cup up to the tip of indicator.
5. Place a clean dry Kohlrausch flask immediately below and directly in line with discharging jet.
6. Insert a clean thermometer and a stirrer in the cup and cover it with a lid.
7. Heat the water filled in the bath slowly with constant stirring until the two temperatures are steady and equal. Then open the vale and collect the oil in the measuring flask of capacity 50cc. conduct the experiment for different temperatures and note down the observations.
8. Lift the ball valve and start the stop watch. Oil from the jet flows into the flask.
9. Stop the stop watch when lower meniscus of the oil reaches the 50 ml mark on the neck of receiving flask.
10. Record the time taken for 50 ml of the oil to collect in the flask.
11. Repeat the experiment to get more readings.

Precautions:

1. The oil should be filtered thoroughly a muslin cloth to remove solid particles that may clog the jet.
2. The receiving flask should be placed in such a manner that the oil stream from jet strikes the neck of receiving flask and do not cause any foaming.
3. After each reading the oil should be completely drained out of receiving flask.

Observation Table:

S.no	Specification of Oil	Temperature ^{0}C		Density of oil (ρ)	Time in Sec to collect 60cc of oil	Absolute Viscosity (μ)	Kinematic Viscosity (ν)
		Water	Oil				
1	SAE -						
2	SAE -						
3	SAE -						
4	SAE -						
5	SAE -						

Density of oil is measured directly from Temperature Vs Density graph.

GRAPHS:

1. Temperature Vs Density (ρ)
2. Temperature Vs Absolute viscosity (μ).
3. Temperature Vs Kinematic viscosity (ν)

RESULT: - The viscosity of given oil sample using Redwood viscometer no. -------- at___ ^{0}C is ____ Red Wood seconds.

Oil Standards

1. Single Grade oils -SAE J300: SAE 0, 5, 10, 15, 20, 25, 30, 40, 50 or 60.
2. Multi Grade oils- SAE J300: SAE W0, W5, W10, W15, 20, 25, 30, 40, 50 or 60
3. American petroleum Institute- API- SJ, SL, SM, SN, CH-4, CI-4, CI-4 PLUS
4. Indian standard Institution -IS :1448

Results:

EXPERIMENT-4

SAYBOLT VISCOMETER (Universal Tip)

Aim: To determine the absolute and kinematic viscosities of the given lubrication oil at different temperatures.

Apparatus:

Say bolt Viscometer, 60 cc flask, stop clock, Dimmer stat, Hydrometer, Measuring jar. Diameter of orifice = 1.11 mm.

Description and Procedure

Ensure proper leveling of the instrument with the help of leveling screws. Wash the cup with kerosene and dry it, then fill the oil bath to at least 5 mm above the overflow rim of viscometer. Insert thermometers in oil and water baths to measure their temperatures. Then heat the baths electrically and stir the water and oil baths at the same time. When the temperature of oil and water are nearly equal, remove the stopper below the oil cup and collect the oil in a standard measuring flask, at the same time record the time taken to fill the flask up to the mark with the help of a stop watch.

FIG: Say bolt Viscometer

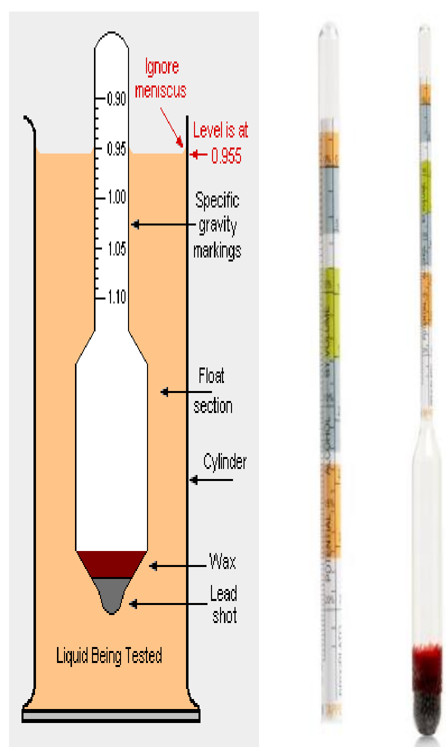


FIG: Hydro meter

Theory: If the flow of an oil through the Say bolt viscometer at 20^0C is 100 Seconds, then efflux time is designated as say bolt universal seconds(SUS).The universal viscometer measures the time required for 60 cc of sample fluid to flow out through an orifice having dimensions of 0.176 cm in diameter and 1.225 cm in length.. Say bolt universal seconds (t) can be converted to kinematic viscosity (v) by the following equation

Kinematic Viscosity (ν) = (At – B/t) cm^2/s. (St)

Where ρ is the density of lubricating oil measured in gm/cm^3.

A = constant of viscometer = 0.0022 cm^2/s^2

B = constant of viscometer =1.8 cm^2.

And t is the time taken to collect 60 cc of oil

Absolute Viscosity (μ) = (Kinematic Viscosity x Density) gm / cm-s.

A scale provided on the hydrometer directly measures specific gravity of oil

Observation

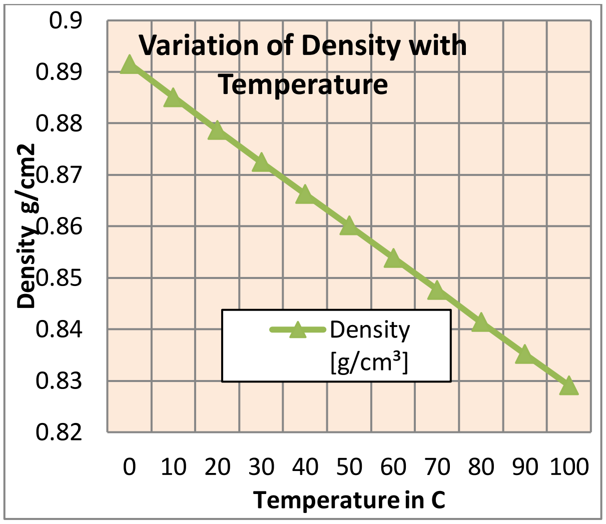
S.NO	Specification of Oil	Temperature ^{0} C		Density of Oil (ρ)	Time n Sec to collect 60ec of oil	Absolute Viscosity (μ)	Kinematic Viscosity (ν)
		Water	Oil				
1	SAE -						
2	SAE -						
3	SAE -						
4	SAE -						
5	SAE -						

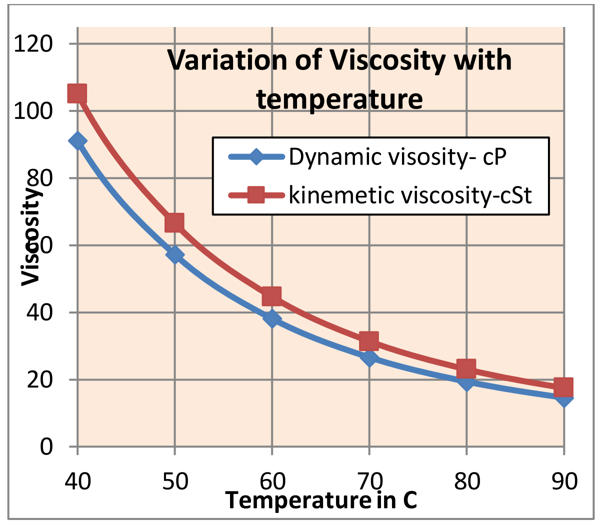
Graphs:

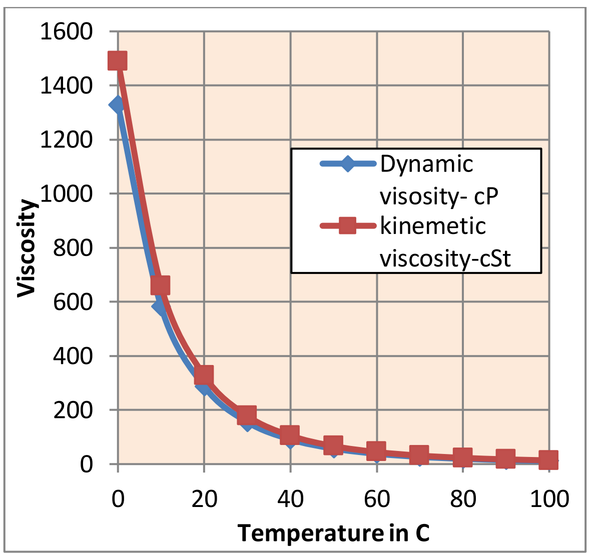
1. Temperature Vs Density.
2. Temperature Vs Absolute viscosity.
3. Temperature Vs Kinematic viscosity.

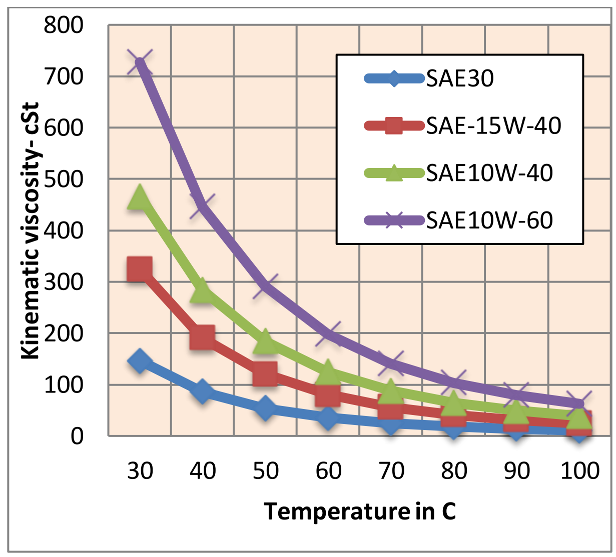
Results:

Typical Graphs









SAE grade	ISO grade	Viscosity In cSt 40°C	100°C	130°C
10W	32	32.6	5.57	3.20
20W	68	62.3	8.81	5.01
SAE 30	100	100	11.9	6.25
SAE 40	150	140	14.7	8.0
5W-20	46	138	6.92	4.17
10W-30	68	66.4	10.2	5.7
10W-40	100	77.1	14.4	8.4

SAE	SAE 50	SAE 40	SAE 30	20W50	10W40	10W30	5W30	5W20
Viscosity @ 40°C (104 °F)	222.10	136.20	85.90	165.90	95.41	69.74	61.98	45.90
Viscosity @ 100°C (212 °F)	20.36	14.70	10.92	18.50	14.00	10.67	10.46	8.36

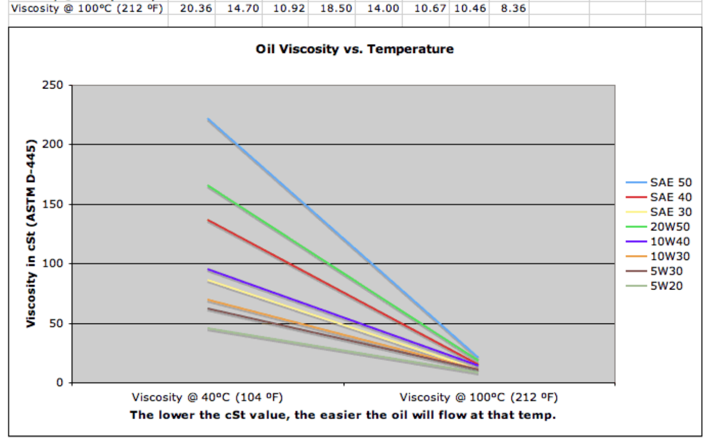


Fig:Variation of Viscosity with Temperature

EXPERIMENT-5

TWO STAGE AIR COMPRESSOR

Aim: To conduct a test on air compressor and to determine volumetric efficiency and isothermal efficiency at various delivery pressures.

Apparatus: Two Stage air Compressor Setup

Description:

The air compressor is two stage, reciprocating type. The air is sucked from atmosphere and compressed in the first cylinder. The compressed air then passes through the air intercooler to the second cylinder where it is further compressed. The air further goes to the air reservoir through a safety valve, which operates the electrical switch, when the pressure exceeds the limit.

The test units consist of an air chamber, containing an orifice pate, the manometer, compressor, and an electrical dynamometer type induction motor.

Precaution:

1. The orifice should never be closed; otherwise the manometer liquid (water) will be sucked into the tank.
2. At the end of the experiment the outlet valve at the air reservoir should be opened, as the compressor is to be started again at low pressure, prevent undue strain on the piston.

Specification:

Diameter of low pressure cylinder	= 110 mm
Diameter of high pressure cylinder	= 80 mm
Length of stoke	= 89 mm

Diameter of orifice = 0.014 m

Procedure:

1. The outlet valve is closed.
2. The manometer connections are checked (the manometer may be fitted with water upto the half level).
3. The compressor is started, the pressure develops slowly.
4. At the required pressure, the outlet is opened slowly and adjusted so that the pressure is maintained constant.

Observation:

Atmospheric temperature: _____ ^oC

SNO	Required Delivery Pressure (kgf/cm^2)	Speed of motor (N_m) (rpm)	Speed of Compressor (N_c) (rpm)	Time taken for 10 rev of wattmeter (t) in (second)	Manometer Reading in (cm)		High Pressure Gauge reading (P_h) (kgf/cm^2)
					h_1	h_2	
1							
2							
3							
4							
5							
6							

Calculation:

1. Volumetric Efficiency
2. Isothermal Efficiency

1. Calculation of Volumetric Efficiency.

$$\text{Volumetric Efficiency} = \frac{\text{Actual volume of air entering the compressor per second at NTP}}{\text{Theoretical volumes of air entering the compressor per second}}$$

Where,

Actual volume of air entering the compressor is determined using the reading of manometer fixed to the air chamber

Actual volume of air entering the compressor at RTP = $V_{a(RTP)} = Cd * a * \sqrt{2gH}\ m^3/sec$.

Where C_d = Coefficient of discharge = 0.64,

a = Area of orifice in m2 = $\frac{\pi d^2}{4}$

d= diameter of orifice meter = 0.014 m.

H = difference of pressure in manometer in meters of air = $\frac{(h_1 - h_2)}{100} x \frac{\rho_{water}}{\rho_{air}}$ meters of air.

NOTE: (h1- h2) is in cm which can be taken from tabular column.

ρ_{water} (Density of water) = 1000 kg/m^3.

ρ_{air} (Density of air) = ____ kg/m^3. To be calculated at the atmospheric pressure and temperature

Actual volume of air entering the compressor at NTP = $V_{a(NTP)} = \frac{V_{a(RTP)} * 273}{\text{Room temp in } ^oK}\ m^3/sec$

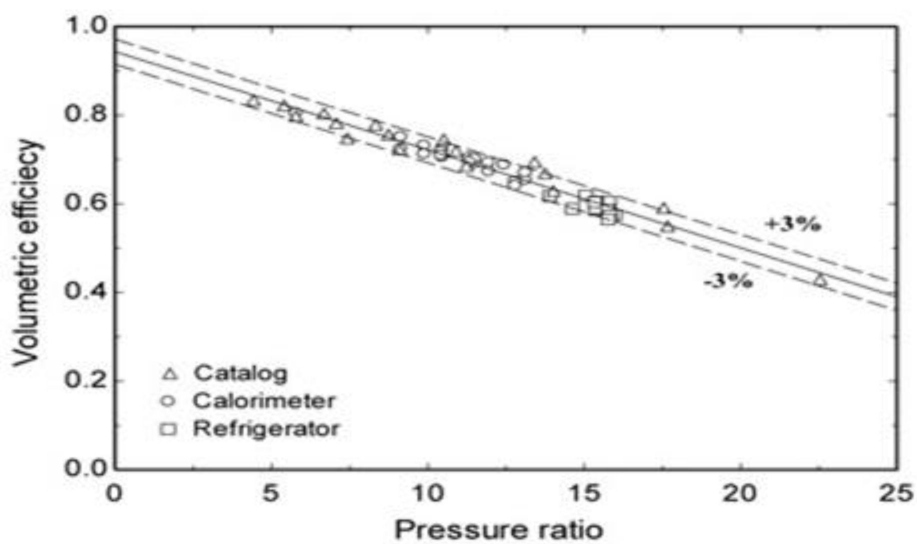
Theoretical volume of air entering the compressor per second = Piston displacement of the Low pressure cylinder during the suction stroke per second = $\frac{\pi * d_2 * L * N_c}{4 * 60}\ m^3/sec$.

Where D = Diameter of Low pressure cylinder = 110 mm = 0.11m

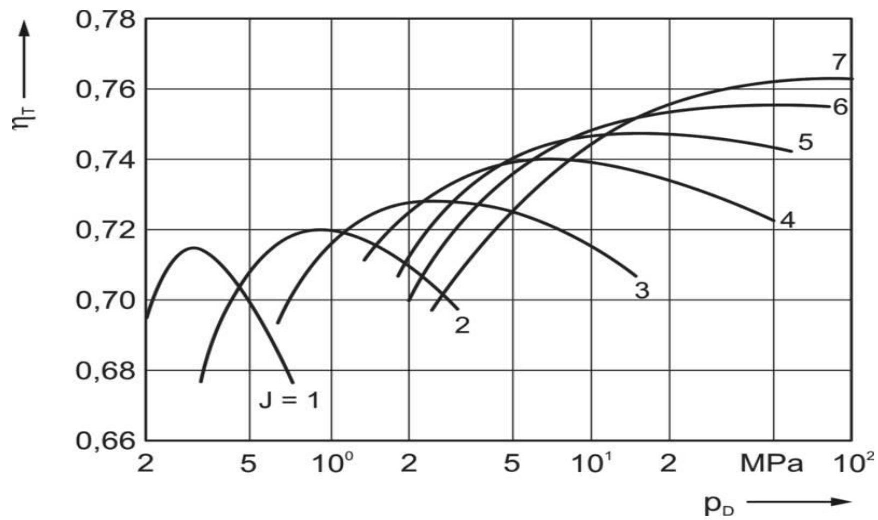
L = Length of stroke which is common for both the cylinders =89mm = 0.089 m.

N_c = Speed of compressor (rpm)

Substituting (a) and (b) in equation (l), we get the volumetric efficiency of the compressor.



Correlation between the volumetric efficiency and pressure ratio.



2. Calculation of Isothermal Efficiency.

$$\text{Isothermal efficiency} = \frac{\text{Work done during isothermal cycle}}{\text{Actual work done on air}}$$

$$\text{Isothermal efficiency} = \frac{\text{isothermal power in kilowatts}}{\text{Shaft input in kilowatts}}$$

Shaft Input = Wattmeter reading in kW x transmission Efficiency x Motor Efficiency.

= ___________ kW x 0.85 x 0.95

150 revolution of wattmeter - 1 k W hr

10 revolutions of wattmeter - 1/15 kW hr

Let t is the time taken for ten revolutions in seconds.

$$\text{Wattmeter Reading} = \frac{3600}{15 \text{ x } t} \text{kW}$$

Isothermal power = Theoretical power supplied assuming single stage isothermal compression from atmospheric pressure to deliver pressure.

Considering Isothermal compression

W.D/cycle = $P_1 V_1 \ln r$, Note: V_1 is in (m^3)

And power supplied assuming single stage isothermal compression = $P_1 V_1 \ln r$.

Where V_1 is volumetric flow rate in m3/sec

Isothermal power = $P_{atm} * V_{a\,(RTP)} * \ln r$.

Where r = compression ratio = $\frac{V_1}{V_2}$

During isothermal process $P_1 V_1 = P_2 V_2$

i.e. $\frac{V_1}{V_2} = \frac{P_2}{P_1}$ (1 kgf/cm^2 = 0.981 x 10^3 N/m^2)

Isothermal Power = $P_{atm} * V_{a\,(RTP)} * \ln(P_2/P_1) = P_{atm} * V_{a\,(RTP)} * \ln(P_{out}/P_{in})$.

NOTE: P_{in} = 101.3 kN/m^2 & P_{out} = High Pressure Gauge reading = $P_H + P_{atm}$

RESULTS:

S.No	Delivery Pressure (N/m^2)	η_{iso}	η_{vol}
1			
2			
3			
4			
5			

EXPERIMENT-6

VALVE TIMING DIAGRAM FOR A 4-STROKE SINGLE CYLINDER VERTICAL DIESEL ENGINE

Aim: To draw the valve timing diagram of the given 4-stroke single cylinder vertical diesel engine.

Apparauts: Single Cylinder Cut Section Model

Description: The given engine is a single cylinder vertical 4-stroke Diesel Engine. The inlet and exhaust valves are operated with the help of cams on the camshaft. A fuel injector is present to start the combustion process.

Procedure: The flywheel of the engine is rotated by hand in clock wise direction. The TDC and BDC positions are marked on the flywheel. Then the flywheel is slowly rotated from TDC position. The inlet valve will start opening just before the end of exhaust stroke or before the starting of suction stroke i.e, just before TDC. This can be checked by the slackness of the push rod. During the suction stroke the inlet valve remains open and then it gradually starts closing. The inlet valve is completely closed after the start of the compression stroke. Before the end of the compression stroke, Fuel is injected into the cylinder chamber by means of fuel injector and this indicates the start of ignition process and the fuel injector and this indicates the start of ignition process and fuel injector moves back after sometime and when the piston starts moving down indicates the end of ignition process. After the compression stroke, the expansion stroke starts (piston comes down) during expansion stroke (or it opens before the start of exhaust stroke). The exhaust valve closes after the start of suction stroke. This can be checked by the slackness of the push rod. All the corresponding angles in degrees can be directly read form the protractor which is fixed to the fly wheel. The degrees are then represented in the diagram as the crank angle.

Reference Information: The diagram which shows the position of crank of four stroke cycle engine at the beginning and at the end of suction, compression, expansion, and exhaust of the engine are called as Valve Timing Diagram. The extreme position of the bottom of the cylinder is called "Bottom Dead Centre" [BDC]. The position of the piston at the top of the cylinder is called "Top Dead Centre" [TDC]. In an ideal engine, the inlet valve opens at TDC and closes at BDC. The exhaust valve opens at BDC and closes at TDC. The fuel is injected into the cylinder when the piston is at TDC and at the end of compression stroke. In an actual engine, the inlet valve begins to open 5°C to 20 °C before the piston reaches the TDC during the end of exhaust stroke. This is necessary to ensure that the valve will be fully open when the piston reaches the TDC. If the inlet valve is allowed to close at BDC, the cylinder would receive less amount of air than its capacity and the pressure at the end of suction will be below the atmospheric pressure. To avoid this the inlet valve is kept open for 25° to 40°after BDC. Exhaust valve opening and closing Complete clearing of the burned gases from the cylinder is necessary to take in more air into the cylinder. To achieve this exhaust valve is opens at 35° to 45° before BDC and closes at 10° to 20° after the TCC. Because of this both inlet valve and exhaust valve remains in open for some angle. The crank angles for which the both valves are open are called as overlapping period. This overlapping is more than the petrol engine.

For Diesel engines the fuel valve opens at 10° to 15 °before TDC and closes at 15° to 20° after TDC. Evaporation of the fuel will be difficult, if all the fuel is supplied at once. This is because better evaporation and mixing fuel.

In case of petrol engine, Ignition of the fuel occurs 35^0 before TDC, this is to allow the time delay between the spark and the commencement of combustion. For high speed engines, higher values of angles are desirable to take into account the short time interval. Different engines/ vehicles use different valve timings.

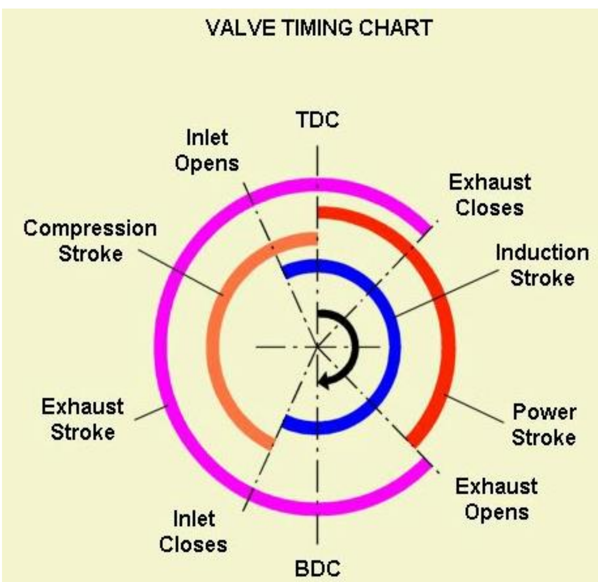


FIG: Valve timing diagram for four stroke engine

Observation

T.D.C to I.V.O = ________________ Suction Angle = Degrees

T.D.C to EVC = _________________ Compression Angle =

B.D.C to I.V.C = ________________ Power stroke =

B.D.C to E.V.O = ________________ Expansion Stroke =

Start of Ignition = _______________ Ignition Angle =

End of Ignition = ________________ Angle of Overlap =

Angle of Overlap=________________

Conclusion: Opening of inlet valve is less than the opening of exhaust valve.

Port timing diagram

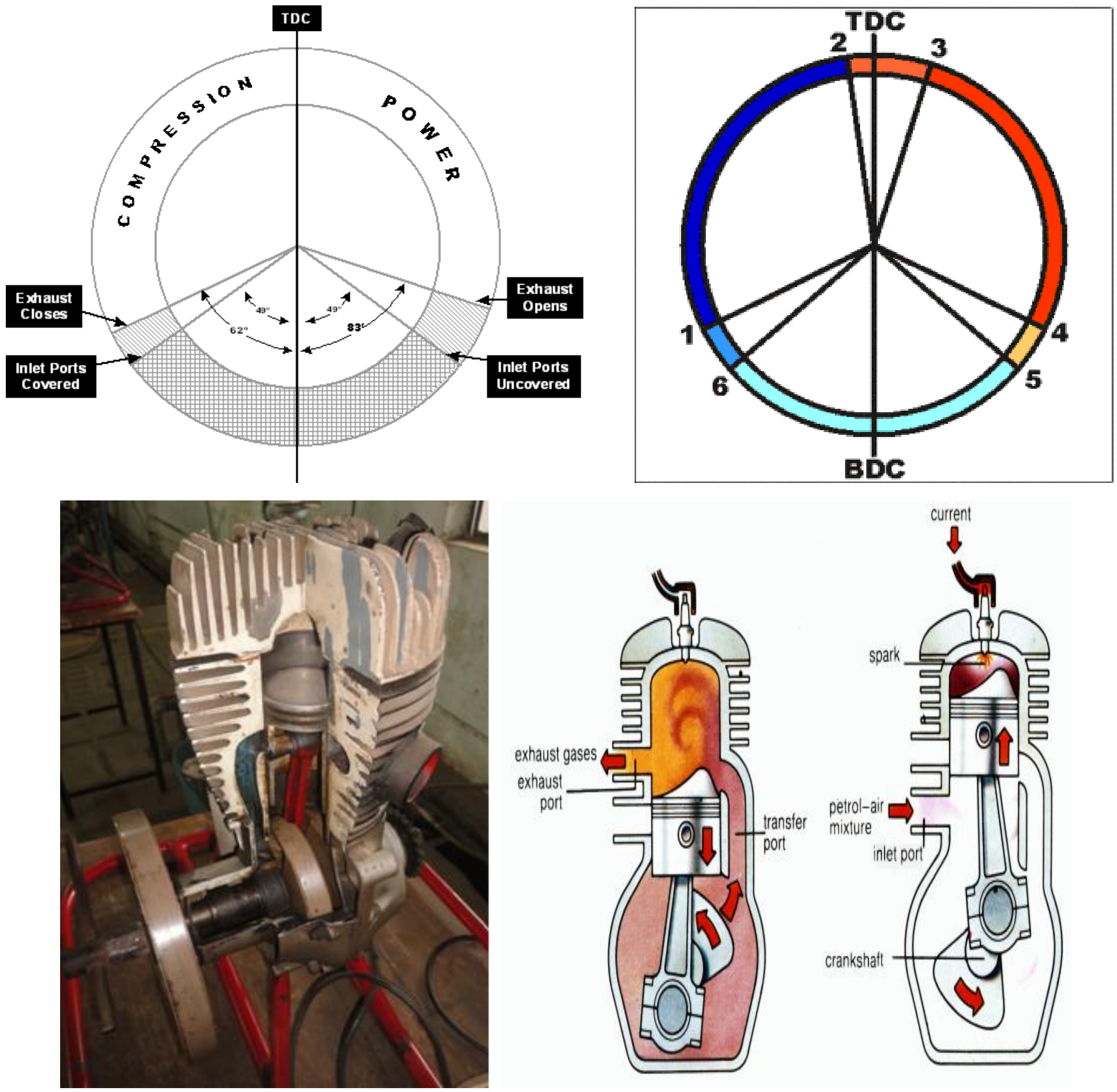


FIG:Port timing diagram for two stroke engine

EXPERIMENT-7

PERFORMANCE TEST ON 4-S, 4 CYLINDER PETROL ENGINE (MPFI)

Aim: To conduct a performance test on the given 4-S, 4 cylinder water cooled petrol engine.

Apparatus: MPFI Engine Setup and Stop Watch

Specification of the Engine:
Bore And Stroke = 84 mm x 82 mm

Rated Power Output = 75 HP at 5000 RPM

Orifice diameter = 25 mm

Arm length = 0.358 m.

Description of the Test Rig:

The test rig consist of 4-S, 4 cylinder petrol. Engine (water cooled) is coupled to Hydraulic dynamometer. The different Hydraulic loading is achieved by operating the hand wheel on the dynamometer. Exhaust gas calorimeter is provided with Rota meter. Separate cooling water line is provided to the engine with Rota meter. The whole instrumentation is mounted on self-contained unit ready for table operation.

Procedure:

1. Check the petrol in petrol tank and switch on the console.
2. Observe all the indicators in ‘ON’ position and allow cooling water to flow through engine.
3. Allow petrol and start the engine keeping the load in minimum position.
4. The engine is set to the required speed by operating speed regulator knob provided on the control panel.
5. Apply load to the engine by operating the hand wheel on the Hydraulic Dynamometer.
6. Adjust the speed regulator to any desired speed, and note down the corresponding values.
7. Increase the load on the engine by operating hand wheel on the hydraulic Dynamometer.
8. Now the speed of the engine decreases, attain the normal speed by adjusting the load without adjusting the throttle valve, and note down the corresponding readings again.
9. Repeat the experiment for 4 to 5 loads and tabulate the readings and perform calculation for various parameters.
10. Note down all the readings and repeat the experiment for different loads by cutting off the other cylinders one at a time.

Fig: 4 stroke 4 cylinder petrol engine (MPFI)

Observation:

S.no	Load W (kg)	Engine Speed (rpm)	Time for 20 gm of fuel consumption (T_f) sec	Manometer Reading (h_1-h_2) cm
1				
2				
3				
4				
5				

Calculations:

1. Brake Power (BP) = $\frac{2\pi NT}{60000}$ kW

   T = W x R (Load x Arm Length) N-m

   R = 0.358 m.

   W = (Load in kg x 9.81) N.

2. Total Fuel Consumption per min (TFC, n kg / hr).

   TFC = m_f x 60 kg/hr

   m_f = mass of fuel consumed per min.

3. Specific Fuel Consumption (SFC).

   SFC = $\frac{TFC}{BP}$ kg / kW-hr

4. Brake Thermal Efficiency.

   $$\eta_{Bth} = \frac{BP \times 60}{m_f \times CV}$$

   CV for petrol = 44100 kJ/ kg.

5. Volumetric Efficiency (η_{vol})

   $$\eta_{vol} = \frac{V_a}{V_{th}} \times 100\%$$

   V_a = C_d x A x $\sqrt{2gh}$ m^3/s.

   Where Cd = Coefficient of discharge = 0.62

   A = $\frac{\pi d^2}{4}$ Where d = diameter of orifice = 25 mm

   $$H = \frac{h_2 - h_1}{100} \times \frac{\rho_{water}}{\rho_{air}}$$

Where ρ_{water} = 1000 kg/m^3, ρ_{air} = 1.293 kg/m^3.

V_{th} = Theoretical Volume $n \text{ x } \frac{\pi D^2}{4} \text{ x } L \text{ x } \frac{1}{2} \text{ x } \frac{N}{60}$ m^3/s

Where n = number of cylinder, D = Diameter of cylinder = Bore (D) = 80 mm, L = 82 mm

Hence, $\eta_{vol} = \frac{V_a}{V_{th}} \text{ x} 100\%$

6. Air Fuel Ratio (A/F).

$$A / F = \frac{m_a}{m_f}$$

Where $m_a = V_a$ x 60 x ρ_{air} kg/min., m_f = mass of fuel consumed per minute.

Table of Calculation:

S.no	Speed (rpm)	Fuel Consumed (kg/hr)	Air Consumed (kg/hr)	A/F	SFC	BHP	η_{Bth}	η_{vol}
1								
2								
3								
4								
5								

Graphs:

1. BP Vs SFC.
2. BP Vs η_{vol}
3. BP Vs η_{Bth}
4. A/F Vs BP.
5. A/F Vs SFC.

Results:

EXPERIMENT-8

MORSE TEST ON 4-S, 4 CYLINDER MPFI PETROL ENGINE

Aim: To measure the indication power and mechanical efficiency of multi cylinder four stroke petrol engine by Morse test.

Apparatus: MPFI Engine Setup and Stop Watch

Specifications: Type 4 cylinder, 4-stroke, water cooled petrol engine(Hindustan Motors), Bore: 84 mm, Stroke: 82 mm, arm length(R) = 858 mm, Power and compression ratio: 9:1.

Description:

The engine is a 4 stroke, 4 cylinder, water cooled petrol engine. The output shaft is connected in a hydraulic dynamometer through a flexible coupling and the brake power is determined by running the engine at the required speed. The fuel inlet is connected to engine in raises with water tank.

Reference Information: The purpose of Morse Test is to obtain the Indicated Power and the mechanical efficiency of a multi-cylinder engine. During the test the engine is run at a constant speed and at same throttle opening. First the BP. of the engine with all cylinders operative is measured by means of dynamometer. Next, the BP. of the engine is measured with each cylinder rendered inoperative one by one by shorting the spark plug(Cutting off the power supply to the spark plug) in case of petrol engine (by cutting off the fuel supply in case of diesel engine).

When one cylinder is cut off, power developed is reduced and speed of engine falls. Accordingly, the load on the dynamometer is adjusted so as to restore the engine speed. This is done to maintain FP constant, which is considered independent of the load and proportional to the engine speed. The observed difference in BP between all cylinders firing and with one cylinder cut off is the IP of the cut off cylinder. Summation of IP of all the cylinders would then give the total IP of the engine under test.

Procedure

1. The engine is started by self starter.
2. The engine is allowed to run and the dynamometer water flow is regulated such that the rpm of the engine is constant.
3. The fuel flow rate, dynamometer reading, air flow rate readings are noted.
4. Cut off one cylinder and adjust the load such that the speed becomes to its original value and readings are noted
5. The difference in the output is a measure of the indicated power of the cutoff cylinder.

6. Repeat the experiment by cutting off remaining cylinders one by one.

Precautions:

(i) The BP should be measured as soon as possible after making cylinder inoperative. (ii) The dynamometer load should be adjusted soon to bring the speed to its constant value for the test otherwise the engine may race. In order to plot IP, BP and η_m series of tests should be conducted at predetermined engine speeds because BP varies with load and speed.

Observation & Tabulations

S.no.	Cylinder Condition	Engine Speed- N rpm	Load -kg	BP- kW	IP- kW
1	All cylinders are firing			BP=	IP=
2	First cylinder cut off			BP1=	IP1=
3	Second cylinder cut off			BP2=	IP2=
4	Third cylinder cut off			BP3=	IP3=
5	Fourth cylinder cut off			BP4=	IP4=

Calculations:

1. When all cylinders are firing, total brake power

   $BP=\frac{2\pi NT}{60 \times 10^3}$ kW $= BP_1+BP_2+BP_3+BP_4$

   T = (loading kg x 9.81) x arm length R

   Where R = 0.358 m

2. B.P. when first cylinder is cut off (no power stroke for first cylinder)

   $BP^1=\frac{2\pi NT}{60 \times 10^3}$ kW , $BP^1= BP_2+BP_3-BP_4 -FP_1$ (Frictional power of first cylinder)

   Indicated power $IP_1 = BP - (BP^1) = (BP_1+BP_2+BP_3+BP_4) - (BP_2+BP_3+BP_4 -FP_1)$

   $IP_1 = BP_1 + FP_1$

3. B.P. when 2nd cylinder is cut off

   $BP^2=\frac{2\pi NT}{60 \times 10^3}$ kW Indicated power $IP_2 = BP - BP^2 = BP_2 + FP_2$

4. B.P. When 3rd cylinder is cut off

   $BP^3=\frac{2\pi NT}{60 \times 10^3}$ kW Indicated power $IP_3 = BP - BP^3 = BP_3 + FP_3$

5. B.P. When 4th cylinder is cut off

   $BP^4 = \frac{2\pi NT}{60 \text{ x } 10^3}$ kW   Indicated power $IP_4 = BP - BP^4 = BP_4 + FP_4$

6. Total indicated power $IP = IP_1 + IP_2 + IP_3 + IP_4$

   Mechanical Efficiency = $\frac{\mathbf{BP}}{\mathbf{IP}}$

Graphs: Plot IP, BP and η_m

Result and Conclusions:

IP for each cylinder and total IP are determined. Mechanical efficiency is ___ %.

EXPERIMENT-9

HEAT BALANCE SHEET ON 4-S SINGLE CYLINDER VERTICAL DIESEL ENGINE WITH EDDY CURRENT DYNAMOMETER

Aim: To conduct a performance test and heat balance analysis on the given vertical 4-Stroke Cylinder water cooled Diesel Engine (Make-Field Marshal).

Apparatus: Single Cylinder Diesel Engine Setup with Stop Watvh.

Specification:

Cylinder Bore (D) = 80 mm

Stroke length = 110 mm

Orifice Diameter (d) = 17.1 mm

Arm Length = 184 mm

Description of The Test Rig:

Field Marshal 4-Stroke single cylinder vertical diesel engine is used for this test. It is a water cooled engine coupled to the eddy current dynamometer. The exhaust gas from the engine is fed to the exhaust gas calorimeter.

Fig: 4 stroke single cylinder disel engine


Fig: 4 stroke single cylinder disel engine

Procedure:

1. Start the engine and run at no load at rated speed for a few minutes, keeping the cooling water flow and fuel supply, keep the Eddy current dynamometer electronic torque controller on zero position.
2. Observe the fuel flow from fuel gauge and note down the time for consumption of 10 cc of fuel at no load.
3. Note down the time taken for water flow from the flow meter, for measuring cooling water flow rate and also find the difference in manometric heads.
4. Inlet and Outlet cooling water temperatures and also the exhaust gas temperature are to be measured.
5. After ‘no load’ readings, Load the engine through the eddy current dynamometer’s torque controller in steps of 2 or 3 kg.
6. Repeat the same procedure at different loads.

Flow Diagram of Engine

T_1 = Engine Cooling Water Inlet temperature.

T_2 = Engine Cooling Water Outlet temperature.

T_3 = Exhaust Gas Calorimeter Water Inlet Temperature.

T_4 = Exhaust Gas Calorimeter Water Outlet Temperature.

T_5 = Exhaust Gas Inlet

T_6 = Exhaust Gas Outlet.

T_7 = Suction Air Temperature

m_f = Mass flow rate of fuel.

m_a = Mass flow rate of air

m_w = Mass flow rate of cooling water

m_{wc} = Mass flow rate of Calorimeter water.

m_g = Mass of Exhaust Gas

Observation:

S.no.	Load W (kg)	Speed N (rpm)	Time for 10 cc of fuel T_f in (sec)	Manometer readings in water column			BP (kW)	SFC Kg/kW-hr	η_{vol}	η_{Bth}
				h_1	h_2	(h1-h2)cm				
1										
2										
3										
4										
5										
6										

1. **Brake Power (BP)** = $\frac{2\pi NT}{60x10^3}$ kW

   Torque T = W x R (W x 9.81) x R N-m.

   Where W = load at sprig balance (kg)

   R = Arm length = 0.184 m

2. **Mass of fuel Consumed per min (m_f).**

   $m_f = \frac{\alpha \text{ x Sp Gravity of fuel x 60}}{\text{t x1000}}$

   where α = 10 cc of fuel

   T = time in sec

   Specific Gravity of Diesel = 0.82 (to be measured)

   Total Fuel Consumption (TFC) = m_f x 60 kg / hr.

3. Specific Fuel Consumption (SFC)

$$SFC = \frac{(mf \times 60)}{BP} \, kg / kW - hr$$

4. Brake Thermal Efficiency (n_{Bth})

$$\eta_{Bth} = \frac{BP \times 60}{m_f \times CV}$$

CV for diesel = 45,455 kJ / kg.

5. Volumetric Efficiency (n_{vol})

$$\eta_{vol} = \frac{V_a}{V_{th}} \times 100\%$$

$$V_a = C_d \times A \sqrt{2gh} \quad m^3/s$$

Where

Cd = Coefficient of discharge = 0.62

$A = \frac{\pi d^2}{4}$ where d = diameter of orifice = 17.1 mm

$$H = \frac{h_2 - h_1}{100} \times \frac{\rho_{water}}{\rho_{air}}$$

Where $\rho_{water} = 1000 \, kg / m^3$

$\rho_{air} = 1.2 \, kg/m^3$ at the atm. temperature

V_{th} = Theoretical Volume = $n \times \frac{\pi D^2}{4} \times L \times \frac{1}{2} \times \frac{N}{60} \, m^3 / s$

Where n = number of cylinder

D =Diameter of cylinder = Bore (D) = 80 mm

Hence,

$$n_{vol} = \frac{V_a}{V_{th}} \times 100\%$$

6. Air Fuel Ratio (A/F).

A/F = $\mathbf{m_a / m_f}$

where $m_a = V_a \times 60 \times \rho_{air}$ kg/min

.

Heat Balance Sheet Observation:

(Flow rates on minute basis)

S.no.	Load	Speed	Jacket cooling water			Exhaust gas Calorimeter			Exhaust gas		
			Flow rate m_w	Inlet Temp T_1 °C	Outlet Temp T_2 °C	Flow rate m_{wc}	T_3 °C	T_4 °C	T_5 °C	T_6 °C	T_7 °C
1											
2											
3											
4											

Calculation:

1. Heat supplied by fuel $= \frac{TFC}{60} \text{ x } CV = Q \text{ kJ / min}$

2. Heat equivalent to BP developed

Q_1 = BP x 60 kJ/min

3. Heat taken away by engine cooling water.

$Q_2 = m_w C_w \Delta T_w$

Where,

C_w = 4.18 kJ/kg K

ΔT_w = T2 – T1

$m_w = \frac{LPH}{60} = m_w$ kg/min.

6. Heat of Exhaust gases

$Q_3 = m_g C_{pg} \Delta T_{ge}$

$m_g = m_a + m_f$

C_{pg} = 1.005 kJ / kg K.

$\Delta T_{ge} = T_6 - T_5$

6. Q4 = Heat of Exhaust gas calorimeter water = (mw Cp ΔT)

7. Heat Unaccounted for Q5= Q - ($Q_1+Q_2+Q_3+Q_4$) kJ/min

Heat Balance Sheet on minute basis.

Item	KJ/min	%
i. Heat Supplied by Fuel (Q)		
ii. Heat Equivalent to BP (Q_1)		
iii. Heat Absorbed by Cooling water (Q_2)		
iv. Heat Absorbed by Exhaust Gases (Q_3)		
v. Heat Absorbed by Exhaust gas Calorimeter (Q_4)		
vi. Heat Unaccounted for $Q_5=Q-(Q_1+Q_2+Q_3+Q_4)$		

Precautions:

1. Before fresh starting of the engine, make sure about the engine oil level at the engine crank case.
2. Keep the engine at no load while starting and stopping.
3. After completion of the experiment allow water to flow for about 3-5 min which will make the engine and Exhaust gas calorimeter get cooled.

Graphs:

1. BP Vs SFC
2. BP Vs n_{vol}
3. BP Vs n_{Bth}

Result: Performance characteristics are determined and heat balance sheet is drawn for the given Field Marshal Engine.

EXPERIMENT-10

PERFORMANCE TEST ON 4-S, 4 CYLINDER MPFI PETROL ENGINE

Aim: To conduct a performance test on the given 4-S, 4 cylinder water cooled Petrol Engine.

Apparatus: MPFI Engine Setup with Stop Watch.

Specification:

Bore & Stroke = 84 mm x 82 mm

Rated Power Output = 75 HP at 5000 rpm

Orifice diameter = 25 mm

Arm length = 0.358 m.

Description of The Test Rig:

The test rig consist of 4-S, 4 cylinder petrol Engine (water cooled) is coupled to Hydraulic dynamometer. The different Hydraulic loading is achieved by operating the hand wheel on the dynamometer. Exhaust gas calorimeter is provided with Rota meter. Separate cooling water line is provided to the engine with Rota meter. The whole instrumentation is mounted on self contained with ready for table operation.

Procedure:

1. Check the petrol in petrol tank and switch on the console.
2. Observe all the indicators in ‘ON’ position and allow cooling water to flow through engine.
3. Allow petrol and start the engine keeping the load in minimum position.
4. The engine is set to the required speed by operating speed regulator knob provided on the control panel.
5. Apply load to the engine by operating the hand wheel on the Hydraulic Dynamometer.
6. Adjust the speed regulator to any desired speed, and note down the corresponding values.
7. Increase the load on the engine by operating hand wheel on the hydraulic Dynamometer.
8. Now the speed of the engine decreases, attain the normal speed by adjusting the load without adjusting the throttle valve, and note down the corresponding readings again.
9. Repeat the experiment for 4 to 5 loads and tabulate the readings and perform calculation for various parameters.

10. Note down all the readings and repeat the experiment for different loads by cutting off the other cylinder one at a time.

OBSERVATION:

S.no.	Load W (kg)	Engine Speed (rpm)	Time for 20 gm of fuel consumption (T_f) sec	Manometer Reading (h1-h2) cm
1				
2				
3				
4				
5				

Calculations:

1. Brake Power (BP) = $\frac{2\pi NT}{60000}$ kW

   T = W x R (Load X Arm Length) N-m.

   R = 0.358 m

   W = (Load in kg x 9.81) N

2. Total Fuel Consumption pen min (TFC, kg/hr).

   TFC = m_f x 60 kg /hr

   m_f = mass of fuel consumed per min

3. Specific Fuel Consumption (SFC)

   $$SFC = \frac{TFC}{BP}\, kg/kW - hr$$

4. Brake Thermal Efficiency

   $$\eta_{Bth} = \frac{BP \times 60}{m_f \times CV}$$

   CV for petrol = 44100 kJ / kg.

5. Volumetric Efficiency (n_{vol})

   $$\eta_{vol} = \frac{V_a}{V_{th}} \times 100\%$$

   $V_a = C_d \times A \sqrt{2gh}$ m^3/s

Where

Cd = Coefficient of discharge = 0.62

$A = \frac{\pi d^2}{4}$ where d = diameter of orifice = 25 mm

$H = \frac{h_2 - h_1}{100} \times \frac{\rho_{water}}{\rho_{air}}$

Where $\rho_{water} = 1000\ kg/m^3$

ρ_{air} = _____ kg/m³

V_{th} = Theoretical Volume = $n \times \frac{\pi D^2}{4} \times L \times \frac{1}{2} \times \frac{N}{60}\ m^3/s$

Where n = number of cylinder

D =Diameter of cylinder = Bore (D) = 80 mm

(L) = 80 mm

Hence, $\eta_{vol} = \frac{V_a}{V_{th}} \times 100\%$

6. Air Fuel Ratio (A/F).

$A/F = \frac{m_a}{m_f}$

where $m_a = V_a \times 60 \times \rho_{air}$ kg/min

m_f = mass of fuel consumed per minute.

Table Of Calculation:

S.no	Speed (rpm)	Fuel Consumed (kg/hr)	Air Consumed (kg/hr)	A/F	SFC	BHP	η_{Bth}	η_{vol}
1								
2								
3								
4								
5								

Graphs: Draw the following graphs

1. BP Vs SFC
2. BP Vs n_{vol}
3. BP Vs n_{Bth}
4. A/F Vs BP
5. A/F Vs SFC

Result:

EXPERIMENT-11

PERFORMANCE TEST ON 4-S SINGLE CYLINDER VARIABLE COMPRESSION RATIO DIESEL ENGINE COUPLED TO AC GENERATOR

Aim: To conduct the performance test on four stroke cylinder Diesel engine connected to an alternator.

Apparatus: VCR Engine with Stop Watch.

Description: Diesel engine is a single cylinder, four stroke developing about SHP, 3600 rpm. The engine is coupled to an alternator through a coupling. Heaters are provided for loading. The alternator is supplied from a tank through a fuel measuring glass by which fuel consumption is found. Air supplied to the engine in the air box with an orifice plate allowing a controlled supply. Manometer is provided to measure the drop in pressure across he orifice.

Procedure: Start the engine by automatic switch. Now load the engine by switching on the loads provided for the heater. Increase the speed to maximum and note down the readings in voltmeter, Ammeter, Manometer and time for10cc of fuel vary the load.

Specifications:

Brake diameter D = 85 mm

Stroke length, L = 110 mm

Orifice diameter, d = 20 mm

C_d = 0.64.

Compression ratio, r= 21.99, 24.5, 20.03, 18.35

Calorific value of Diesel fuel (CV) = 39150 kJ/kg.

Formule:

1. $BP = \frac{V \times I}{1000 \times n_{alt}}$ kW.

   $\eta_{alt} = 90\% = 0.9$

2. m_f =(volume of fluid x specific gravity of fluid x 60) / (time taken for 10cc of fuel consumed)

3. $n_{Bth} = \frac{BP\,x\,60}{CV\,x\,m_f}$

4. $SFC = = \frac{m_f\ x\,60}{BP} kg/KW\,hr$

5. $n_{vol} = \frac{V_a}{V_s}$

V_a = Actual Volume of air taken inside the cylinder during suction stroke.

$=C_d\ A\ \sqrt{2gH}\,m^3/s$

$H = \frac{h_2 - h_1}{100} x \frac{1000}{1.16}$

V_s = Swept Volume

$= \frac{\pi}{4} \frac{D^2LN}{60}\ m^3/s$

Observation, Readings & Calculations:

S,no.	Speed (rpm)	V Volts	I Amps	Manometer Reading		Time for 10cc consumption of fuel (sec)
				h1 (cm)	h2(cm)	
1						
2						
3						
4						
5						

S.no.	BP (Kw)	SFC (kg/kW-hr)	n_{Bth}(%)	n_{vol}(%)
1				
2				
3				
4				
5				

Speed (rpm)	Volts	Amps	Manometer Reading		Time for 10cc consumption of fuel (sec)
			h1 (cm)	h2(cm)	
1					
2					
3					
4					
5					

S.NO	BP (kW)	SFC (kg/kW-hr)	n_{Bth}(%)	n_{vol}(%)
1				
2				
3				
4				
5				

Result:

The break thermal efficiency = ___________

The volumetric efficiency is = ___________

Table of Calculation:

S.no	Speed (rpm)	Fuel Consumed (kg/hr)	Air Consumed (kg/hr)	A/F	SFC	BHP	η_{Bth}	η_{vol}
1								
2								
3								
4								
5								

Graphs: Draw the following graphs

1. BP Vs SFC
2. BP Vs η_{vol}
3. BP Vs η_{Bth}
4. A/F Vs BP
5. A/F Vs SFC

Result and Conclusions:

EXPERIMENT-12

PERFORMANCE TEST ON 4-STROKE SINGLE CYLINDER DIESEL ENGINE

Aim: To conduct performance test on 4-stroke, single cylinder, diesel engine coupled to an AC generator.

Apparatus: Single Cylinder Diesel Engine with Stop watch

Specification:

Bore = 68 mm and Stroke Length = 78 mm

Orifice Diameter = 14 mm and C_d = 0.64

Speed = 3600 rpm

Description: Diesel Engine is a single cylinder, 4 stroke developing about 5 HP at 3600 rpm. This engine is coupled to an AC generator through a flexible coupling. Loading of the generator is done by switching on the bulbs. Fuel is supplied through the burette to measure the fuel consumption. Air is supplied to the engine via air box with an orifice. Manometer is provided to measure the pressure drop across the orifice.

Procedure:

Start the engine and apply the load by switching the required bulbs, increase the speed to maximum and note down the readings of voltmeter, ammeter, manometer and time taken for 5cc for fuel. Vary the speed and tabulate the readings. Conduct the test by varying the load keeping the speed constant by adjusting accelerator.

Observations:

S.no	Speed N (rpm)	Voltage (V)	Current (A)	Time for 5cc of fuel (sec)	Manometer Reading (cm)		Difference Manometer (h) (cm)	BP	SFC	n_{Bth}	n_{vol}	A/F
					h_1	h_2						
1												
2												
3												
4												
5												

Calculation:

1. $BP = \frac{(V \times A) \times 1.36}{(1000 \times \eta_G)} KW$

   Where,

   V = Volts

   A = Amps

   $\eta_G = 90\%$

2. $m_f = \frac{(\text{Volume of fuel consumed x Sp Gravity of fuel x 60})}{(\text{Time taken for amount of fuel consumed x 1000})} kg/min$

   $m_f = \frac{(5 \times 0.8275 \times 60)}{(t \times 1000)} kg/min$

   t = time taken for 5 cc of fuel consumed

3. Brake Thermal Efficiency (η_{Bth}) = $\frac{(BP \times 50)}{CV \times m_f}$

   Where m_f = Mass of fuel consumed in kg/min

   CV = 39,150 Kj/kg.

   BP = Brake Power in kW.

4. SFC= $\frac{m_f \times 60}{BP}$ kg/kW-hr

5. Volumetric Efficiency (n_{vol})

   $\eta vol = \frac{V_a}{V_{th}} \times 100\%$

   $V_a = C_d \times a \times \sqrt{2gH}$ m^3/s.

   Where

   C_d = Coefficient of discharge = 0.54

   a= Area of orifice = $\frac{\pi d^2}{4}$ where, d= diameter of orifice = 0.014m.

   $H = \frac{h_2 - h_1}{100} \times \frac{\rho_{water}}{\rho_{air}}$

   Where

   $\rho_{water} = 1000$ kg/m^3.

   ρ_{air} = _____ kg/m^3.to be calculated at room temperature

V_{th} = Theoretical Volume = $\frac{n}{4} \text{ x } \frac{\pi D^2}{2} \text{ x L x } \frac{1}{60} \text{ x } \underline{N}$ m_3/s

Where n = number of cylinder

D = Diameter of cylinder = Bore (D) = 0.068 m

L + Length of Stroke = 0.078 m

Hence,

$$\eta_{vol} = \frac{V_a}{V_{th}} \text{ x } 100\%$$

Graphs:

1. BP Vs SFC
2. BP Vs η_{Bth}
3. BP Vs η_{vol}.

Results and Conclusions:

.

EXPERIMENT-13

EXHAUST GAS ANALYSIS OF PETROL ENGINE USING 5-GAS ANALYZER

Aim: To measure the pollution of petrol engine at varying speeds and loads and analysis of exhaust gases.

Apparatus: MARS 5-Gas Analyser with Printer.

Description: Test rig consists of a Petrol Engine coupled with Hydraulic dynamometer. The engine is a 4 cylinder, 4 stroke, water cooled petrol engine. The exhaust gas is passed through the calorimeter. Sampling probe is inserted into the tail pipe of the engine to measure the exhaust gases with the help of five gas analyzer. The results are viewed on the computer system.

Fig: Exhaust gas analyzer

Specifications of Five gas Analyzer	Standard Accessories	Gases Measured
Operating System: PIC- Micro Controller	Equipment- Multi Gas Analyzer	CO (Carbon Monoxide)
Display: LCD Display	Power Supply Mains Cord	CO2 (Carbon Dioxide)
Interface: RS-232 & RS-485	RS-232 Cable	HC (Hydro Carbon)
Power Supply: 230 V AC. 50 Hz, 12 V DC	Sampling Probe	O2 (Oxygen)
Dimensions: 450mm X 300mm X 120mm Approx, Weight-5 kg	PC Control Software	NOx(Nitric Oxide)
Approval: ARAI, Pune, India		Lambda Measurement

Technical Specifications:

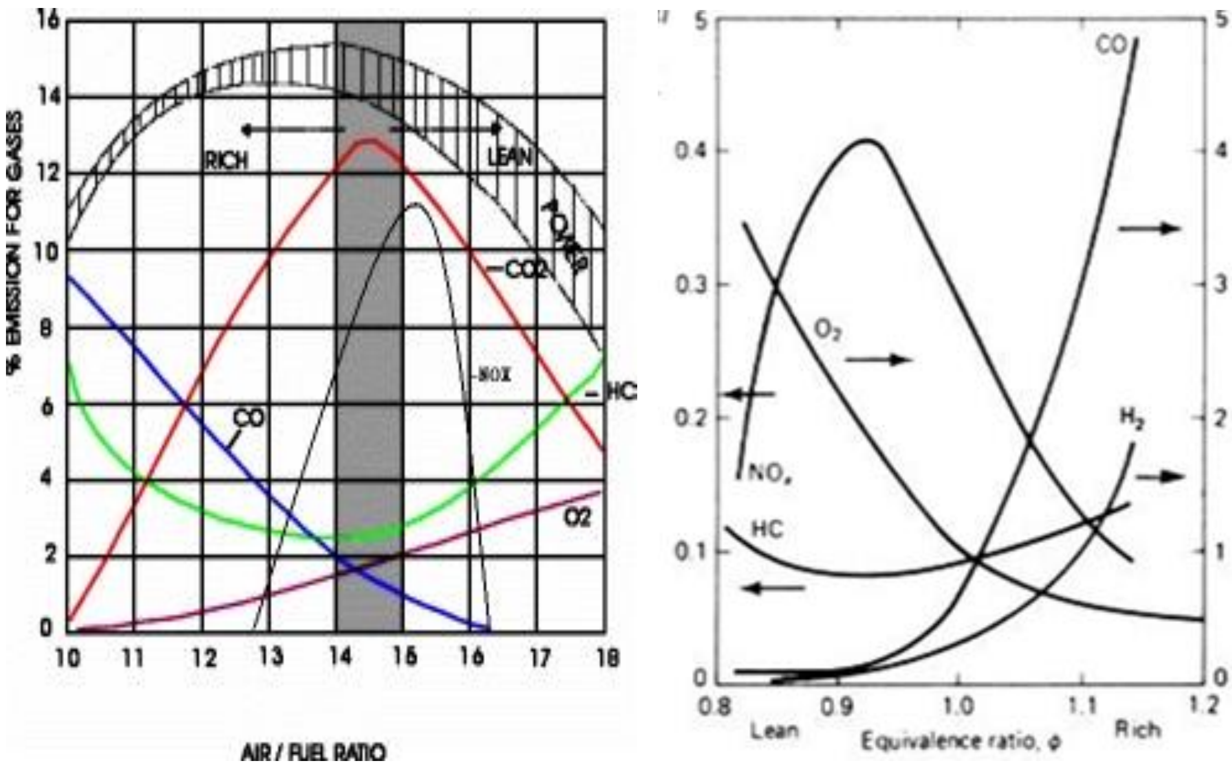
Measurement	Range	Resolution
CO	0 -10% Vol	0.001% Vol.
HC	0 -15000 ppm	1 ppm
CO2	0-20% Vol	0.01% Vol.
O2	0-25%	0.1% Vol.
NOx	0 -5000 ppm	1 ppm Vol.
Oil temperature ^{0}C	0 -150	1
Lambda (λ)	0.2 -2.0 %	0.001

Five Gas Exhaust Analysis Theories:

The five gasses measured (for petrol emissions) by the latest technology exhaust analysers are: HC, CO, CO2, O2 and NOx. The measurements are helpful in troubleshooting both emissions and driveability concerns. All five of these gasses, especially O2 and CO2, are excellent troubleshooting tools. Use of an exhaust gas analyser will allow us to narrow down the potential cause of driveability and emissions concerns and save diagnostic time.

The chemistry equation:

Fuel (hydrogen, carbon, sulphur) + Air (nitrogen, oxygen) = Carbon dioxide + water vapour + oxygen + carbon monoxide + hydrocarbon + oxides of nitrogen + sulphur oxides.



Volume of CO, CO2, HC, O2 and NOx for different air fuel ratios / equivalence ratio

Complete (Good) Combustion:

In ideal combustion, the fuel will burn completely and not have any "leftovers". We supply petrol and air into the combustion. (Normal air is about 20.7% oxygen and nitrogen 78% by volume). The nitrogen doesn't burn, it just goes along and expands with the heat, helping to push down the piston.
1 liter of petrol we burn, the tailpipe puts out about a I liter of water (The exhaust consist of 8-10% of water vapour and ideal air fuel ratio is 14.7:1) and all the Nitrogen comes out in the form oxides.
In good combustion: $HC + O_2 + N_2 = H_2O + CO_2 + N_2$ (carbon dioxide, water and nitrogen comes out of the tail pipe)
There are a few other exhaust components which impact driveability and/or emissions diagnoses, which are not measured by Gas analyzers. They are:

- Water vapour (H_2O)
- Sulphur Dioxide (SO_2)
- Particulate carbon soot (C)

Sulphur dioxide (SO_2) is sometimes created during the combustion process from the small amount of sulphur present in gasoline. During certain conditions the catalyst oxidizes sulphur dioxide to make SO_3, which then reacts with water to make H_2SO_4 or sulphuric acid. This sulphuric acid will corrode the tail pipe. Finally, when sulphur and hydrogen react, it forms hydrogen sulphide gas. This process creates the rotten egg odour you sometimes smell when following vehicles on the highway. Particulate carbon soot is the visible black "smoke you see from the tailpipe of a vehicle that's running very rich.

Incomplete (BAD) Combustion:

Incomplete Combustion the fuel is not burned properly for different reasons. Due to incomplete combustion HC, CO are released in to the atmosphere along with CO_2, NOx and small percentage of other exhausts. HC + NOx + Still air + Sunlight will be converted in to Smog. CO leads to global warming

The diagram represents the Exhaust Gases relationship to the Air/Fuel ratio that enters the engine. In proper combustion process CO_2 is produced and is highest percentage and the HC lowest. The Power is also highest at this point. The CO and O_2 have the lowest values at the "ideal" point

The following are the gases that the 5- Gas analyzer measures in a petrol engine:

- **HC - Hydrocarbons**, concentration of the exhaust in parts per million (ppm). Unburned Petrol represents the amount of unburned fuel due to incomplete combustion exiting through the exhaust. An approximate relationship between the percentage of wasted fuel through incomplete combustion and the ppm of HC is about 1/200 (1.0% partially burned fuel produces 200 ppm HC, 10%=2000 ppm HC, 0.1%=20 ppm HC).

- **CO -Carbon Oxide**, concentration of the exhaust in percent of the total sample. Partially Burned Petrol, This gas is formed in the cylinders when there is incomplete combustion and an excess of fuel. Therefore excessive CO contents are always a sign of an overly rich mixture (more fuel or less air) preparation. (The CO should have become CO_2 but did not have the time or enough O_2 to became real CO_2 so it is exhausted as CO instead.) CO Is Highly Poisonous Odorless Gas.

- **CO_2 - Carbon Dioxide**, concentration of the exhaust in percent of the total sample. This gas gives a direct indication of combustion efficiency. It is generally 1-2% higher at 2500 RPM than at idle. This is due to improved gas flow resulting in better combustion efficiency. Maximum is around 16%. At night the trees convert CO_2 in to Oxygen. Preserve them.
- **O_2 - Oxygen**, concentration of the exhaust in percent of the total sample. Free O_2 occurs in the exhaust when there is an excess of air in the mixture. The O_2 content increases sharply as

soon as Lambda (Air - Fuel equivalence ratio (λ) - λ = 1.0 is at stoichiometry, rich mixtures λ < 1.0, and lean mixtures λ > 1.0.)- Actual air fuel ratio to ideal air fuel ratio) rises above 1. Taken with the CO2 maximum, the oxygen content is a clear indicator of the transition from rich to lean mixture range.With rich mixture most of the oxygen is burned during combustion. While very lean mixture more O2 escapes "un-combusted" so the level rises.

- **NOx - Oxides of Nitrogen** (This is only seen by a 5-gas analyser) NOx emissions rise and fall in a reverse pattern to HC emissions. As the mixture becomes leaner more of the HC's are burnt, but at high temperatures and pressures (under load) in the combustion chamber there will be excess O2 molecules which combine with the nitrogen to create NOx. NOx increases in proportion to the ignition timing advance, irrespective of variations in A/F ratio. A high combustion temperature increases in NOx formation. NOx is very dangerous lethal gas and air pollutant.
- **A/F ratio or Lambda -** Calculated Air/Fuel Ratio or Lambda value based on the HC, CO, CO_2 and O_2 concentrations. The ideal (Stoichiometric) A/F is 14.7 liters air to 1 liter fuel or 14.7/1. Lambda is defined as the ratio of Actual AFR to stochiometric AFR**. The *λ is < 1 for Rich mixture and λ >1 for lean mixture***. For ideal condition λ=1. For example, lambda=0.8 corresponds to an air/fuel ratio of (0.8x14.7):1=11.76:1(Very rich air fuel mixture)

General Rules of Emission Analysis

- If CO goes up, O_2 goes down, and conversely if O_2 goes up, CO goes down. CO readings are an indicator of a rich running engine and O2 readings are an indicator of a lean running engine.
- If HC increases as a result of a lean misfire, O_2 will also increase
- CO_2 will decrease in any of the above cases because of an air/fuel imbalance or misfire
- An increase in CO does not necessarily mean there will be an increase in HC. Additional HC will only be created at the point where rich misfire begins (3% to 4% CO)
- High HC, low CO, and high O_2 at same time indicates a misfire due to lean or EGR diluted mixture
- High HC, high CO, and high O2 at same time indicate a misfire due to excessively rich mixture.
- Normal to marginally high HC, Normal to marginally low CO, and high O_2 indicates a misfire due to false air or marginally lean mixture

Procedure: The petrol engine is started by self starter, speed of the engine is varied by the accelerator. Five gas analyzer consists of keys, F1, F2, ….., F6 of which F5, F6 issued to reset the values of initial readings. Maintaining the engine at a particular speed a sampling probe is inserted into the tail pipe of the engine exposing to the exhaust gases and then pressing F5 gives us the required output data. This is repeated for 5-6 readings.

Observations:

Room temperature = ^{0}C

S.no.	Load W (kg)	Speed N (rpm)	Time for 10 cc of fuel T_f in (sec)	Manometer readings in water column			Air Fuel ratio	CO	CO2	HC	O2	NOx	Lambda (λ)
				h_1 cm	h_2 cm	(h1-h2) cm							
1													
2													
3													
4													
5													
6													

Graphs:

1. Graphs are drawn with speed on X-axis and percentage of gases liberated on y-axis.
2. Graphs are drawn with Air fuel ration on X-axis and percentage of gases liberated on y-axis

The following table lists some of the results possible for different Air Fuel ratio

Condition	Results
Too Lean	Poor engine power, Misfiring at cruise speeds Burned valves, Burned pistons Scored cylinders, Spark knock or ping
Slightly Lean	High mileage, Low exhaust emissions Reduced engine power, Slight tendency to knock or ping

Stoichiometric	Best all-around performance
Slightly Rich	Maximum engine power, Higher emissions Higher fuel consumption, Lower tendency to knock or ping
Too Rich	Poor fuel mileage, Misfiring, Increased air pollution Oil contamination, Black exhaust

Typical Properties Of Petrol							Composition of petrol	
Density	*710-770 kg/m³ @ 15 ⁰C*		Enthalpy of vaporization	310 kJ/kg			% Aromatics	*15-20*
Colorific value (Net)	*43500 – 44350 kJ/kg*		Anti knock index:	84			% Saturates	*50-60*
Flash Point	*Below 10 ^{0}C*		Sulphur % mass	0.1 max.			% Naphthenes	*15-20*
Fire Point	*Below 20 ^{0}C*		Lead.	0.013 max. gm/lit			% Olefins	*25-30*
Auto ignition temperature	*450 ^{0}C*						% Benzene	3-5

Euro Norms for Diesel vehicles

Year	Stage	CO	HC	CO2	HC+Nox	Nox	PM
1992		17.3-32.6	2.7-3.7				
1996		5-9			2-4		
2000	EURO 1	2.72-6.9			0.97-1.7		.14-0.25
2005	EURO 2	1.0-1.5			0.7-1.2		0.08-0.17
2010	EURO 3	.64-0.95			0.56-0.86	0.5-0.78	.05-0.1
2010	EURO 4	0.5-0.74			0.3-0.46	0.25-0.39	0.025-0.06

Euro Norms for Petrol vehicles

Year	Stage	CO	HC	CO2	HC+Nox	Nox	PM
1991		14.3-27.1	2.0-2.9				
1996		8.67-12.4	2-2.9				
2000	EURO 1	2.72-6.9			0.97-1.7		
2005	EURO 2	2.2-5			0.5-0.7		
2010	EURO 3	0.10-5.22	0.2-0.29			.15-0.21	.
2010	EURO 4	1.0-2.27	0.1-0.16		0.3-0.46	0.08-0.11	

EXPERIMENT-14

EXHAUST GAS ANALYSIS OF DIESEL ENGINE FOR CARBON DEPOSITS USING SMOKE METER

Aim: To measure the pollution of Diesel engine at varying speeds and loads and analysis of exhaust gases.

Apparatus: MARS Smoke meter with printer.

Description: Test rig consists of a Diesel Engine coupled with electric dynamometer. The engine is a single cylinder, 4 strokes, water cooled Diesel engine. The exhaust gas is passed through the calorimeter. Sampling Probe is inserted into the tail pipe of the engine to measure the exhaust gase with the help of smoke meter. The results are viewed on the computer system

Specifications of Smoke meter	Standard Accessories	Measurement	Range and resolution
Operating System: 32 bit Micro Controller	Equipment- Smoke meter	Hatridge smoke unit HSU	0-99.9 %(0.1%)
Display: LCD Display	Power Supply Mains Cord	K value	0.00-9.99% (0.01)
Interface: USB	RS-232 Cable	Response time	< 0.001 sec
Power Supply: 230 V AC. 50 Hz, 12 V DC	Sampling Probe		
Dimensions:470mmX 362mm X 175mm, Weight-7 kg	PC Control Software		
Approval: ARAI, Pune, India			

FIG:Smoke meter

Fig:Smoke meter

DIESEL EMISSIONS MEASUREMENT –DEFINITIONS

SMOKE:

Smoke is a general term used to describe the cloudy, hazy, emanations that result from the burning o f organic substances. It consists of solid and/or liquid particles or droplets that are so small that they tend to remain suspended in air for extended periods of times varying from seconds to years. Although smoke is often visible to the human eye, much of it is not. The size and content of the particles or droplets comprising smoke very much affect our ability (as well as the ability of optical instruments) to "see" it.

PARTICULATE MATTER(PM): Particulate Matter (PM) is very similar to smoke in that it consists of small solids and/or liquids suspended in air; however, the sources of the suspended substances are not necessarily the result of burning organic substances. Dust, sand, abraded material from tires and brakes, salt sprays, and even small water droplets like fo g are some of the other constituents. PM is usually the terminology used from a regulatory complian ce perspective and may be further subdivided into size related classifications such as PM10, PM2.5, etc. PM10 is a classification of PM representing constituents that are less than 10 microns in diameter (PM less than 10 x10-6 meters in size.

OPACITY:

Opacity is a measure of light reduction/loss over a smoke column path usually expressed as a percen tage. An opacity of 10% means that 90% of the source light power remains and 10% has been lost af ter passing through the measurement path. The 90% (0.9) term (the light remaining) is referred to as Transmittance (0-10).

SMOKE DENSITY: Smoke density is a term usually associated with opacity measurements where there is reason to assume that the optical measurement relationships follow the Beer-Lambert exponential laws. The Beer-Lambert Law is usually expressed as T = e-KL where T is transmittance (same as 1-opacity/100), K is the smoke density factor in units of inverse length(L^{-1}), and L is path length of the measured smoke sample column. Conceptually, the smoke density term represents the exponential light loss sensitivity per unit length of the smoke column.

SOOT: Soot is considered by many to be the agglomerated combination of elemental carbon (EC) and organic carbon (OC) in diesel exhaust particulate matter. However, others consider soot to be only the insoluble portion of diesel particulate; hence, elemental carbon.

SMOKE METER:

The term Smoke Meter generally refers to a smoke measuring instrument based on optical property measurements. The classes of instruments that measure the reflective propertiesare generally called Smoke Meters with their results reported in special units called Smoke Numbers. Common reporting scales include Hartridge Smoke Units (HSU), Bosch Smoke Unit (BSU), Filter Smoke Number (FSN), etc.

With few exceptions smoke meters generally operate with optical frequencies in the visible to near i nfra-red spectra. The majority use green light (~550 nm) or deep red light (~680nm) as optical spect ral bands for measurement.

SMOKE NUMBER

Smoke number is a term relating the output of smoke meters (aetholometers) that measure optical properties of smoke on a filter “paper” substrate. A variety of smoke number scales have been devel oped to relate different instrument measurements to the assumed amount of soot being measured. An underlying assumption for such reporting is that soot is the majority or at least most important constituent of the smoke to be measured. Common reporting scales include Hartridge Smoke Units (HSU)(0-99), Bosch Smoke Unit (BSU), Filter Smoke Number (FSN), etc.

Hartridge smoke unit is generally referred as HSU, is used to measure the opacity of the exhaust gases of engines, particularly diesel engine. It is expressed in terms of integers ranging from 0-100 followed by HSU as its dimensional quantity. In India “65 HSU” is being given as the standard quantity to measure the pollution from the exhaust of the diesel vehicle. (A value of 0 indicates perfect transmission, or Zero opacity. A value of 100 indicates total absorption, or complete opacity.

This is referred (in the case of HSU) to a transmission length of 430mm, at 100 ^{0}C and atmospheric pressure. Values in between are not linear with respect to actual absorption) The vehicle exceeding 65 HSU is not fit for running on the roads of India. The unit of hartridge smoke unit is "K m $^{-1}$" which is termed as "Light Absorption Coefficient".

Observations:

Room temperature = ^{0}C

S.no.	Load W (kg)	Speed N (rpm)	Time for 10 cc of fuel T_f in (sec)	Manometer readings in water column			Air Fuel ratio	Smoke density k or HSU
				h_1 cm	h_2 cm	(h1-h2) cm		Range 2.3-3/65-75
1								
2								
3								
4								
5								
6								

Conclusions:

EXPERIMENT-15

PERFORMANCE TEST ON BOILER AND STEAM TURBINE

Aim: To conduct performance test on Boiler and on a two stage impulse steam turbine.

Apparatus: Vashpa Fire Tube Boiler with 2-Stage Impulse Turbine.

Apparatus: Steam generator (boiler), steam turbine coupled to DC generator, electric loading device, tachometer and the measuring instruments.

Technical Specifications:

Equipment	Specifications
Boiler	Fire tube type boiler (Laxmi Make)
Capacity	500 kg/hr from and at 10 ^{o}C
Steam Turbine	2 stage Curtis type (Impulse type) (GE Make)
Maximum load	10 kW
Speed	3000-3600 rpm
Initial Pressure	8-10 bar
Final Pressure	5.5- 4 bar
Condenser Area	4.7 m^2

Description: Almost dry saturated steam at a pressure of 10 bar is supplied to steam tube through a throttle valve. The steam turbine is a 2-stage impulse type (Curtis) exhausting steam into atmosphere (Non-Condensing). A DC electric generator is coupled directly to the steam turbine. It runs at 3000 rpm and speed is maintained constant at all loads by varying in supply of steam to the turbine. Loading is done electrically by lighting rated electric bulbs. Lighting or shutting off bulbs can vary the load.

Procedure: The experiment is started when the boiler pressure reaches around 10 bar. The main stop valve of the boiler is slowly opened and steam is admitted into the turbine until steady state conditions are reached. The pressure and flow of steam is regulated till the turbine speed reaches 3000 rpm and is maintained constant throughout the experiment. The boiler is continuously run and the pressure and water level in the boiler is maintained constant by regulating feed water and blow down. Load is then applied to the steam turbine by lighting electric bulbs.

When steady state conditions are reached initial reading is water level tank, fuel tank, initial pressure and temperature of steam turbine, exhaust pressure, rpm of electric generator, electrical load and other details are noted down. The turbine runs for sometimes, again readings are taken down and quantities calculated. The experiment is repeated and readings are taken at various loads.

Fig: Boiler

Fig: Boiler with impulse steam turbine

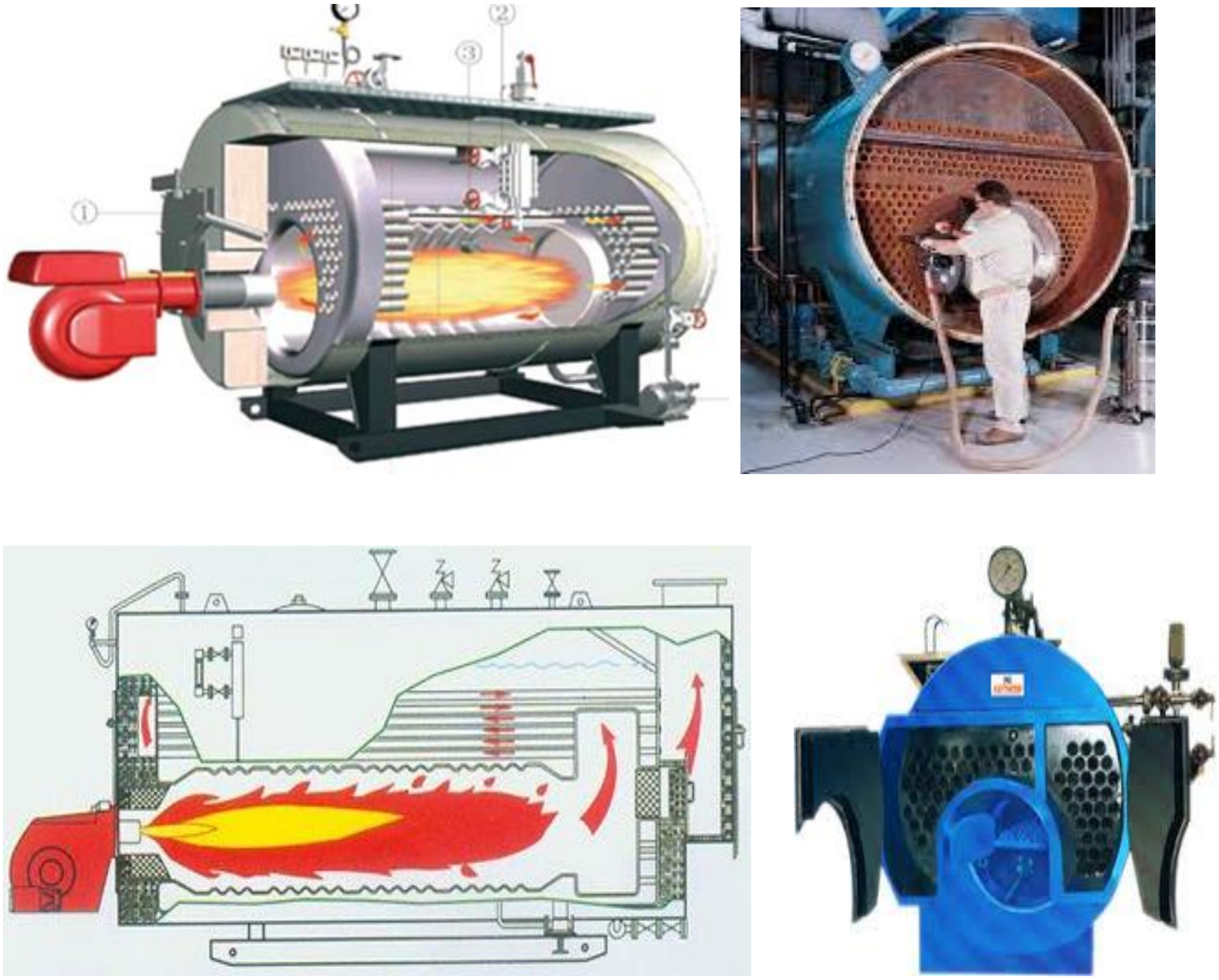


Fig Boiler

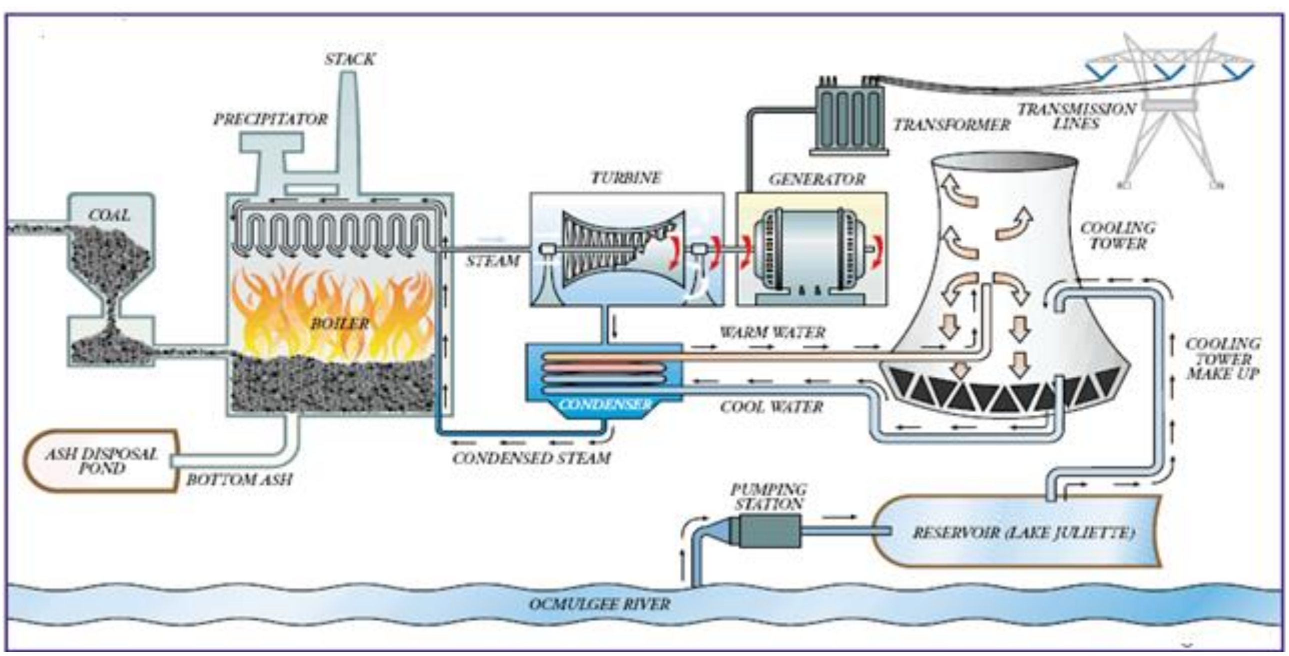
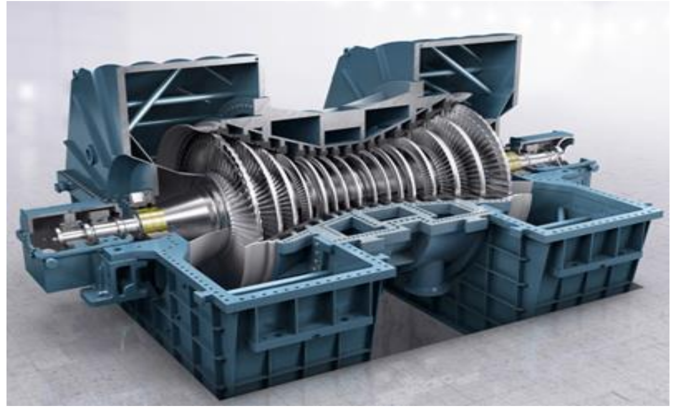
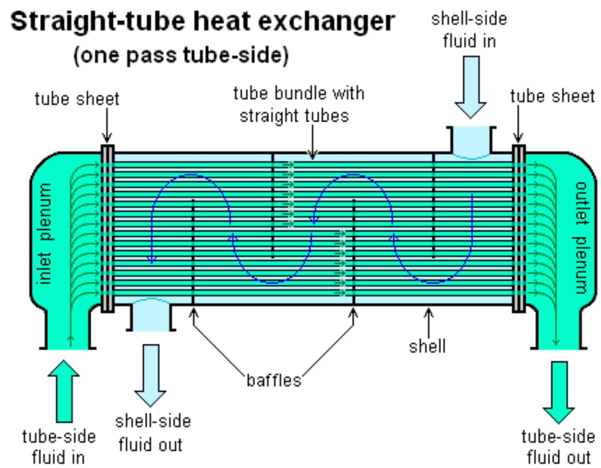


Fig: steam power plant layout

Fig: chimneys





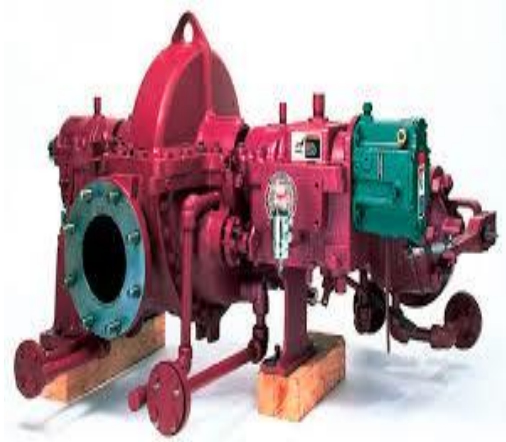


Fig: Turbine Coupled to Generator

Observations:

S.NO	Boiler Pressure P_1 (bar)	Exhaust Pressure P_2 (bar)	Initial Enthalpy h_1(kJ/kg)	Final Enthalpy h_2(kJ/kg)	Enthalpy Of water h_{12}(kJ/kg)	Initial reading of water tank h_{w1}(cm)	Final reading of water tank h_{w2}(cm)
1							
2							
3							

S.no.	Initial Reading of Fuel Tank h_{1f}	Final Reading of Fuel Tank h_{2f}	Mass Flow Rate of Steam m(kg/s)	Mass Flow Rate of Fuel mf (kg/s)	Rankine Efficiency (η_R)	Isentropic Efficiency Of steam Turbine (η_t)	Thermal Efficiency Of the Boiler (η_B)	Overall Efficiency (η_o)
1								
2								
3								

Formulae:

1. The efficiency of Rankine (theoretical ideal cycle) is given by $\eta_R = (h_1 - h_{2s})/(h_1 - h_{f2})$.
2. Output of steam turbine in kW=P / $\eta_{generatorR}$.
3. Input to the turbine = m (h_1-h_{2s})
4. Isentropic efficiency of steam turbine (η_1)= output/input = P /m x (h_1-h_{2s})
5. Thermal efficiency of the boiler (η_B)= m (h_1-h_{f2})/m_f x HCV
6. Overall efficiency of thermal plant $(\eta_o) = (P / m_f)\,x\,HCF$

Where

HCV – Higher Heating Value of fuel.

And m = Area of tank x $\rho_w\, x\, (h_{2w} - h_{1w})/(100\, x\, time) = 5.8\, x\, (h_{2f} - h_{1f})/t$

Where t is time in seconds.

And mf =Area of and x $\rho_f\, x\, (h_{2f} - h_{1f})/(100\, x\, time) = 5.8\, x\, (h_{2f} - h_{1f})/t$

Where t is in seconds.

Conclusions: Hence performance test on Steam Turbine is performed.

EXPERIMENT-16

DETERMINATION OF DRYNESS FRACTION OF STEAM BY SEPERTING AND THROTTLING CALORIMETER

Aim: To determine the dryness fraction of steam by combined separating and throttling calorimeter.

Apparatus: Steam generator (Boiler), separating and Throttling Calorimeter, measuring cylinder and Thermometers.

FIG: Throttling calorimeter

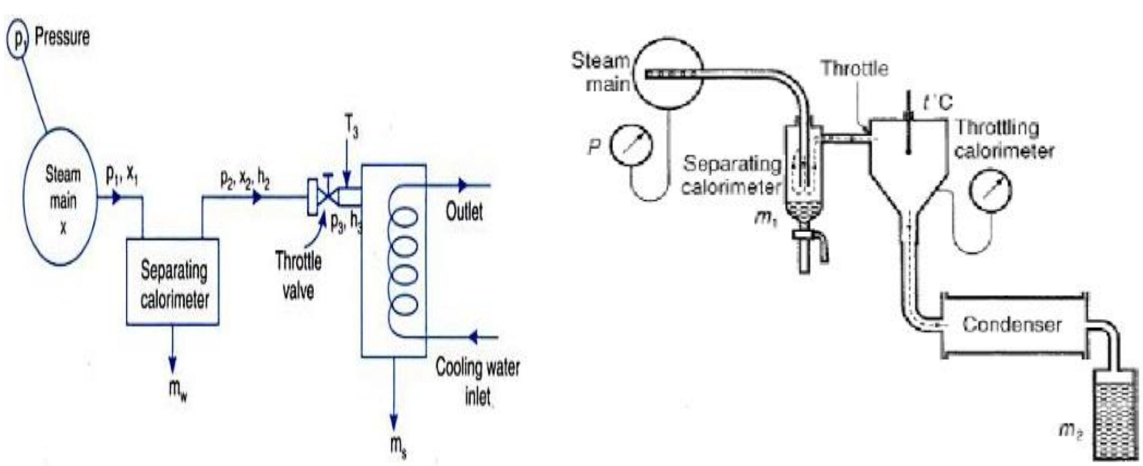
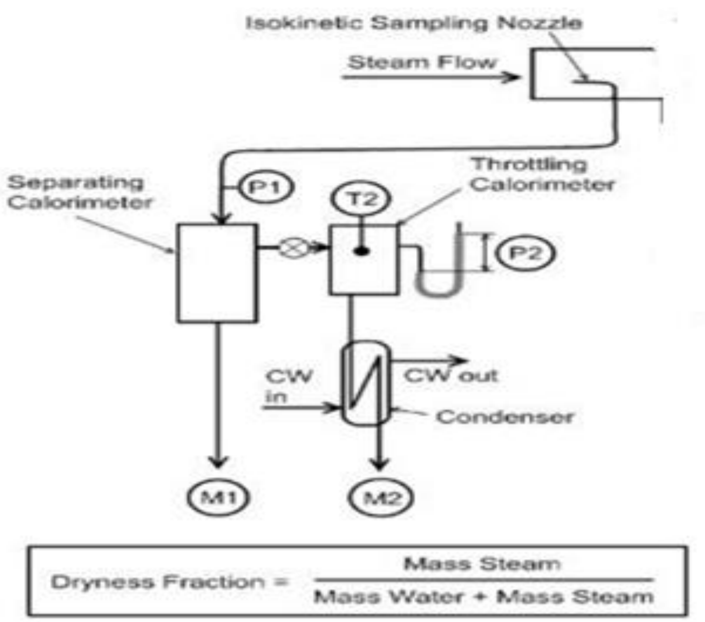


FIG:Line Diagram separating calorimeter

Description: A portion of wet steam from the steam generator is passes through a separator, where it is made to flow round a sharp corner. A large portion of the water carried by the steam separates here, because of higher inertia of the droplets, as compared with that of dry vapor. This water issues from an opening at lower part of the instrument where it is collected in a measuring cylinder. The rest of the steam is throttled in steady flow through an orifice to a pressure $P_2<P_1$, The steam pressure P_2 in the throttling calorimeter is known by manometer reading and temperature tc is noted by a thermometer after throttling.

Separating Calorimeter and Throttling Calorimeter (Combined Calorimeter)

It consists of two concentric chambers, the inner chamber and the outer chamber, which communicates with each other through an opening at the bottom. As the steam discharges through the metal basket, which has a large number of holes, the water particles due to their heavier momentum get separated from the steam and collect in the chamber. The comparatively dry steam in the inner chamber moves up and passes through a narrow orifice (Throttling valve) and enters the Throttling Calorimeter. The steam after throttling process passes through the heat exchanger and condensate is collected.



Combined Calorimeter

Dryness Fraction: The quality of wet steam is usually defined by its dryness fraction. When the dryness fraction, pressure and temperature of the steam are known, then the state of wet steam is fully defined. In a steam plant it is at times necessary to know the state of the steam. For wet steam, this entails finding the dryness fraction. When the steam is very wet, we make use of a separating calorimeter.

If $\mathbf{m_w}$ = mass of water collected in the separating calorimeter for a given time

$\mathbf{m_s}$ = mass of steam passed from the separating calorimeter into the throttling calorimeter

= mass of condensate collected after throttling calorimeter in the same time.

The dryness fraction =

$$X_1 = \frac{m_s}{(m_s + m_w)}$$

Observations: A steady flow condition is established. The pressure before separating calorimeter P_1 (Boiler pressure) is noted and maintained constant throughout the experiment for a given time. Measure m_w, m_s, pressure P_2 and temperature t_c.

S,NO	Inlet Pressure P1 in (bar)	Manometer Reading mm of Hg		Temperature of steam ºC (t_c)	Mass of water kg (m_w)	Mass of condensate in kg (m_s)
		h1	h2			
1						
2						
3						

Calculations:

Dryness fraction is obtained by separating calorimeter.

$$X_1 = \frac{m_s}{(m_s + m_w)}$$

$P_1 = P_g + P_a$

$P_2 = P_a + [(h_1 - h_2)/760] \times 1.013$ in bar (P_a Atmospheric pressure and P_g gauge pressure)

If X2 is dryness fraction of steam entering the throttling calorimeter, then equating total heat of steam before and after throttling.

$(h_f + X_2 h_{fg}) = h_g + C_p(t_c - t_s)$ where Cp = 2.607 kJ/kg K.

$X_2 = [(h_{g-} - h_f) + C_p(t_c - t_s)] / h_{fg}$

The values h_f, h_{fg} are liquid and latent heat obtained from steam tables for pressure P_1, and h_g is total heat obtained from steam tables for dry saturated steam at pressure P_2 at saturation temperature t_s.

The temperature t_c is measured by thermometer, X_2 is then evaluated.

Then X the dryness fraction of steam from the steam generator is the product of X_1 and X_2.

Thus $X = X_1 . X_2$

Conclusions:

Result: