



DEPARTMENT OF MECHANICAL ENGINEERING

Haldia, Purba Medinipur, West Bengal

HALDIA INSTITUTE OF TECHNOLOGY

PRACTICAL MANUAL

(Assessment Instrument and Instruction Items)

Course Name	THERMAL ENGINEERING LABORATORY
Course Code	PC-ME 592
Laboratory Name	THERMAL ENGINEERING LABORATORY
Programme	B. Tech in Mechanical Engineering
Semester / Year	V th Semester/3 rd Year
Academic Session	2026–27

Faculty-in-Charge & Technical Staff

Faculty-in-Charge	Dr. Pradip Mondal & Dr. Ashok Kumar Bera
Co-Faculty (if any)	Dr. Nilabha Sankar Mitra
Technical Staffs	Mr. Ramkrishna Maity
	Mr. Santanu Maity, Mr. Shahbaz Khan



Vision

To impart quality, industry-relevant teaching-learning that blends knowledge and skill to produce industry-ready mechanical engineering graduates.

Mission Statements

M1: To create qualified and proficient technocrats having contemporary skills through outcome-based and self-learning strategies.

M2: To encourage innovation-oriented and problem-based research capabilities among young engineers through higher studies, in order to nurture the progress of society.

M3: To instill strong ethical values and good professional behaviour, enabling graduates to adopt and absorb emerging changes in the engineering profession.

Program Educational Objective

Graduates of B. Tech. Mechanical Engineering program, four years after graduation will

PEO1: Specify, design, supervise, test, and evaluate engineering skills to design, develop, and implement innovative solutions, systems, and applications in Mechanical Engineering and allied industries.

PEO2: Utilize Mechanical Engineering knowledge to address real-world and societal challenges while pursuing higher studies, research, and professional development.

PEO3: Demonstrate effective individual and collaborative capabilities in multidisciplinary professional environments, with a commitment to lifelong learning and adaptability to evolving technological, industrial, and societal requirements.

Program Specific Outcomes (PSOs)

PSO1: Design, analyze and evaluate mechanical components and systems such as thermal, fluid, manufacturing, design systems and allied engineering solutions.

PSO2: Utilize and evaluate modern engineering tools, software, and techniques to model, analyze, and solve real-world mechanical engineering problems.

PSO3: Demonstrate professional and ethical responsibility, effective communication, and the ability to work in multidisciplinary teams to address societal, industrial, and environmental challenges through sustainable mechanical engineering solutions.



Course Details:

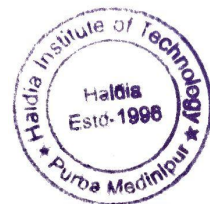
Course Code: PC-ME 592	Category: Professional Core courses	PCIE Marks	40
Course Name: Thermal Engineering Laboratory	Semester: Fifth	PSEE Marks	60
L-T-P: 0-0-3	Credit: 1.5	Total Marks	100
Pre-Requisites: Thermodynamics, Fluid Mechanics Laboratory			
Examination (PSEE): Practical			

Course Content:

Unit	Topics	Hours	CO
UNIT I / Ex 1	Study of 4-stroke IC engine models.	6	CO1
UNIT II / Ex 2	Study of valve timing diagram of diesel engine.	6	CO2
UNIT III / Ex 3 & Ex 4	Determination of the calorific value of a given fuel using bomb calorimeter. Determination of the flash and fire points of fuels.	9	CO3
UNIT IV / Ex 5	Performance test of a 4-stroke single cylinder diesel engine.	9	CO4
UNIT V / Ex 6	Performance test of a multi-cylinder petrol engine by MORSE method.	9	CO5
UNIT VI / Ex 7	Flue gas analysis using multi-gas analyser.	3	CO6
Total		42	

Suggested Reference Books

1. V. Ganesan, I.C. Engines, McGrawHill, 2017.
2. H.N. Gupta, Fundamentals of Internal Combustion Engines, PHI, 2012.
3. J.B. Heywood, Internal Combustion Engine Fundamentals, McGrawHillCo., 1988.
4. H. Cohen, H.I.H. Saravanamuttoo, G.F.C. Rogers, P. Straznickyand, A.C. Nix, Gas Turbine Theory, Pearson, 2019.
5. C.R. Fergusonand, A.T. Kirkpatrick, Internal Combustion Engines, Wiley, 2015.



Course Outcomes:

Upon successful completion of the course, students will be able to:

CO CODES	CO Statement	Knowledge Categories	Cognitive Level
PCME 592.1	Understand the construction, working principles, components, and operating characteristics of four-stroke I.C. engines using cut-section models and engine test rigs.	C	U
PCME 592.2	Understand and plot diesel-engine valve timing diagrams from experimental measurements, identifying valve overlap, lead, lag, and their relationship with engine-operation phases.	C	U
PCME 592.3	Determine and evaluate fuel calorific value, flash point, and fire point using standard laboratory apparatus, comparing results with reference values and assessing fuel suitability.	P	E
PCME 592.4	Evaluate brake power, indicated power, brake thermal efficiency, and specific fuel consumption through load testing of a single-cylinder diesel engine and interpret performance trends.	P	E
PCME 592.5	Evaluate multi-cylinder petrol-engine performance using the Morse test by determining cylinder-wise indicated power and comparing individual cylinder contributions.	P	E
PCME 592.6	Analyse flue-gas composition using a multi-gas analyser, evaluate combustion and emission characteristics, compare emissions with applicable standards, and suggest suitable improvement measures.	P	An



ALIGNING OF COS IN [CL × KC] METRIC

Cognitive Levels (CL)	Knowledge Categories (KC)							
	Factual	Conceptual	Procedural	Meta-cognitive	Fundamental Design Principles	Criteria & Specifications	Practical Constraints	Design instrumentalities
Remember (R)								
Understand (U)		CO1, CO2						
Apply (Ap)								
Analyze (An)			CO6					
Evaluate (E)			CO3, CO4, CO5					
Create (C)								

Assessment Pattern and Assessment Instruments for PCIE & PSEE

Marks allotted	PCIE								PSEE (60)	
	PCAI (40)				PCAII (40)					
	10	10	10	10	10	10	10	10	40	20
CO	Ex1	Ex2	Ex3 & Ex4	VIVA I	Ex5	Ex6	Ex7	VIVA II	GR-A	GR-B (Viva)
CO1	10			10/3					40/6	20/6
CO2		10		10/3					40/6	20/6
CO3			10	10/3					40/6	20/6
CO4					10			10/3	40/6	20/6
CO5						10		10/3	40/6	20/6
CO6							10	10/3	40/6	20/6

CO-PO & CO-PSO Articulation Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3
PCME 592.1	3	2		2	2			1	1		2	3	2	1
PCME 592.2	3	3		3	3			1	1		2	3	3	1
PCME 592.3	3	3	2	3	3	1	2	1	1		2	3	3	2
PCME 592.4	3	3	2	3	3	2	1	1	1	1	2	3	3	2
PCME 592.5	3	3	2	3	3	1	1	2	1		2	3	3	2
PCME 592.6	3	3	2	3	3	3	2	2	1	1	3	3	3	1
Average	3.00	2.83	1.33	2.83	2.83	1.17	1	1.5	1.00	0.33	2.17	3.00	2.83	1.83





THERMAL ENGINEERING LABORATORY (PC-ME 592)

LIST OF ASSESSMENT ITEMS, INSTRUCTION ITEMS

Experiment No.	Name of the experiment	Instruction Item (II)	CO Congruence
EX1	Study of 4-stroke IC engine models.	II1	[CO1]
EX2	Study of valve timing diagram of diesel engine.	II2	[CO2]
EX3	Determination of the calorific value of a given fuel using bomb calorimeter.	II3	[CO3]
EX4	Determination of the flash and fire points of fuels.		
EX5	Performance test of a 4-stroke single cylinder diesel engine.	II4	[CO4]
EX6	Performance test of a multi-cylinder petrol engine by MORSE method.	II5	[CO5]
EX7	Flue gas analysis using multi-gas analyser.	II6	[CO6]



INSTRUCTION ITEM-1(II 1)		
Experiment No.	Name of the experiment	CO Congruence
EX 1	Study of 4-stroke IC engine models.	[CO1]

THEORY:

In four strokes C.I. Engine compression ratio is from 16 to 20. During suction stroke air is inducted. In C.I. engines high pressure. Fuel pump and injectors are provided to inject the fuel into combustion chamber and ignition chamber system is not necessary.

1. **Suction:** During suction stroke, air is inducted through inlet valve.
2. **Compression:** The air inducted is compressed into the clearance volume.
3. **Expansion:** Fuel injection starts nearly at the end of the compression stroke. The rate of injection is such that the combustion maintains the pressure constant inspired of piston movement on its expansion stroke increasing the volume. After injection of fuel, the products of combustion chamber expand.
4. **Exhaust:** The piston traveling from BQC to TDC pushes out the products of combustion out of cylinder.

CONSTRUCTION DETAILS:

1. **Cylinder:** It is a cylindrical vessel in which a piston makes up and down motion.
2. **Piston:** It is a cylindrical component making up and down movement in the cylinder.
3. **Combustion Chamber:** It is the portion above the cylinder in which the combustion of the Fuel-air mixture takes place.
4. **Inlet and Exhaust valves:** The inlet valves allow the fresh fuel-air mixture to enter the combustion chamber and the exhaust valve discharges the products of combustion.
5. **Crank Shaft:** It is a shaft which converts the reciprocating motion of piston into the rotary motion.
6. **Connecting Rod:** The connecting rod connects the Piston with the crankshaft.
7. **Cam shaft:** The cam shaft controls the opening and closing of inlet and Exhaust valves.
8. **Fuel Injector:** It is located at the top of head to inject the fuel into the combustion chamber.

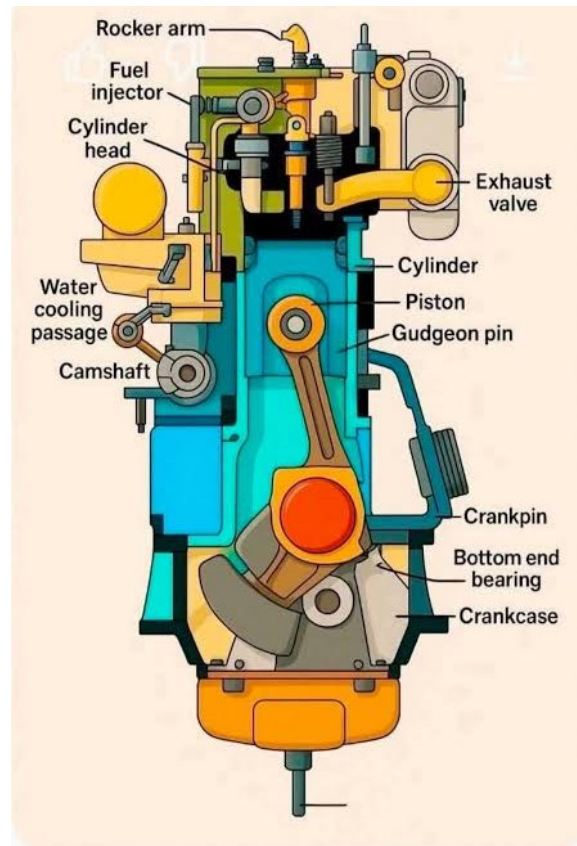


Fig. 1: Cut-section view of the Kirloskar TV-1 engine

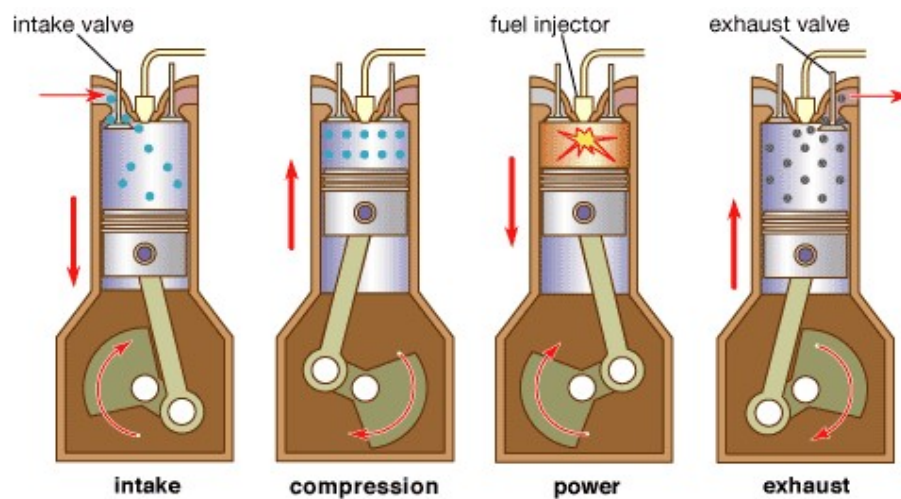


Fig. 2: Sequences of the strokes of the engine.

CONCLUSIONS:



INSTRUCTION ITEM-2 (II 2)		
Experiment No.	Name of the experiment	CO Congruence
EX 2	Study of valve timing diagram of diesel engine.	[CO2]

THEORY:

The valve timing diagram gives an idea about how various operations are taking place in an engine cycle. The four stroke diesel engines have inlet valve to supply air inside the cylinder during suction stroke and an exhaust valve to transfer exhaust gas after combustion to the atmosphere. The fuel is injected directly inside the cylinder with the help of a fuel injector.

The sequence of events such as opening and closing of valves which are performed by cam- follower-rocker arm mechanism in relation to the movements of the piston as it moves from TDC to BDC and vice versa. As the cycle of operation is completed in four strokes, one power stroke is obtained for every two revolution of the crankshaft. The suction, compression, power and exhaust processes are expected to complete in the respective individual strokes. Valves do not open or close exactly at the two dead centers in order to transfer the intake charge and the exhaust gas effectively. The timing is set in such a way that the inlet valve opens before TDC and closes after BDC and the exhaust valve opens before BDC and closes after TDC. Since one cycle is completed in two revolutions i.e. 720 degrees of crank rotations, various events are shown by drawing spirals of suitable diameters. As the timing plays major role in transfer of the charge, which reflects on the engine performance, it is important to study these events in detail.

PROCEDURE:

1. Mark the direction of rotation of the flywheel. Always rotate only in clockwise direction when viewing in front of the flywheel.
2. Mark the Bottom Dead Center (BDC) position on the flywheel with the reference point when the piston reaches the lowermost position during rotation of the flywheel.
3. Mark the Top Dead Center (TDC) position on the flywheel with the reference point when the piston reaches the top most position during the rotation of flywheel.
4. Identify the four strokes by the rotation of the flywheel and observe the movement of inlet and exhaust valves.
5. Mark the opening and closing events of the inlet and exhaust valves on the flywheel.
6. Measure the circumferential distance of the above events either from TDC or from BDC whichever is nearer and calculate their respective angles.
7. Draw the valve timing diagram and indicate the valve opening and closing periods.

FORMULATIONS:

$$\text{Angle} = \frac{L}{X} \times 360^\circ$$

Where,

L - Distance from nearest dead center in mm

X - Circumference of the Flywheel in mm

OBSERVATIONS:

Sl. No.	Description	Distance in mm	Angles in Degrees
		IVO Before TDC	
		IVC After BDC	
		EVO Before BDC	
		EVC After TDC	

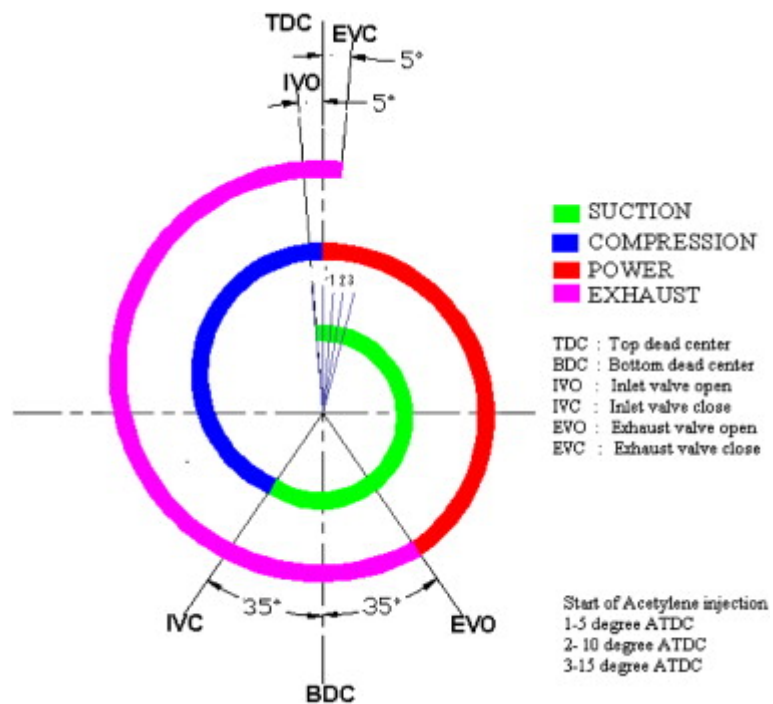


Fig. 3: VTD for a single cylinder 4 stroke diesel engine

CONCLUSIONS:



INSTRUCTION ITEM-3 (II 3)		
Experiment No.	Name of the experiment	CO Congruence
EX 3	Determination of the calorific value of a given fuel using bomb calorimeter.	[CO3]
EX 4	Determination of the flash and fire points of fuels.	

Ex 3 THEORY: A bomb calorimeter will measure the amount of heat generated when fuel is burnt in a sealed chamber (Bomb) in an atmosphere of pure oxygen.

The amount of heat produced by burning the sample must be equal to the amount of heat absorbed by the calorimeter assembly; knowledge of water equivalent of the calorimeter assembly and of the rise in temperature enables one to calculate the heat of combustion of the sample.

APPARATUS:

1. Stainless steel bomb 300cc capacities with electrode and crucible holder
2. Stainless steel crucible
3. Ignition circuit (firing unit)
4. Pressure gauge with copper tubes for filling gas inside the bomb under pressure
5. Nicrome wire 44 swg

TASK:

- Water equivalent of the calorimeter
- Calorific value of the given fuel

PROCEDURE:

1. Weight the sample to cause a temperature rise of 20C to 30C. In the present case 1 gm of benzoic acid is suitable for this desired temperature. Sample should not be less than 0.9 gm and should not be more than 1.1 gm.
2. Connect the nicrome wire across the terminals of the bomb. Tie a known weight of cotton to the firing wire and arrange the ends of the cotton such that they touch the sample
3. Put 1 ml of distilled water in the bomb. Assemble the bomb and charge it slowly with oxygen to a pressure of around $30 \times 10^5 \text{ N/m}^2$ (30 bar) without displacing the original air present in the bomb.
4. Pour sufficient water into calorimeter vessel to cover the flat upper surface of bomb cap
5. Transfer the calorimeter vessel to the water jacket, lower the bomb into the calorimeter vessel and check that the bomb is gas tight. If gas escapes from the bomb, discard the test.
6. Setup the apparatus and keep the stirrer on
7. After five minutes the charge is fired by use of special transformer and firing unit



8. Readings are continued for further thirteen minutes. If the rate of change of temperature is not constant at the preliminary period, extend the preliminary period until it is constant
9. Determine the rate of change (which follows the chef period) by taking readings at one minute intervals for, at least five, preferable ten minutes.
10. Remove the bomb from the calorimeter vessel. The bomb is allowed to remain unopened for thirty minutes after the charge is fired, to allow the acid mist to settle and release the pressure and dismantle the bomb.

PRECAUTIONS:

The operator must follow the following basic points in order to operate the oxygen bomb safety.

- a) Do not use too much sample. The bomb cannot expected to withstand the effects of combustible charges which liberates more than 10000 calories. This generally limits the total weight of combustible material (sample plus gelatin), firing oil or any combustion aid to not more than 1.1 gm. Do not charge with more oxygen than necessary and do not fire the bomb if an overcharge of oxygen should accidentally be admitted.
- b) Do not fire the bomb if gas bubbles are leaking from the bomb when it is submerged in water.
- c) Stand back from the calorimeter, immediately after firing. Keep clear of the top of the calorimeter. If the bomb explode it is more likely that the force of explosion will be directed upward.

FORMULATIONS:

The effective heat capacity of the system is determined by burning pure and dry benzoic acid weighing not less than 0.9 gm and not more than 1.1 gm. Determine the corrected temperature rise T , from the observed test data, also titrate the bomb washings to determine the nitrite acid corrosion and measure the unburned fuse fire, compute the energy equivalent by substitution in the following equation:

$$W = (H \times M + E_L + E_3) / T$$

Where,

W = Energy equivalent of calorimeter in cal/ $^{\circ}\text{C}$

H = Heat release due to combustion of standard benzoic acid, cal/gm = 6319 cal/gm

M = Mass of standard benzoic acid sample (gm) = 1 gm

T = Corrected temperature rise ($^{\circ}\text{C}$) = observed rise of temperature ($T_a - T_0$) + cooling correction

E_L = Correction for additional heat release due to use of nitric acid (i.e. alkali solution) for titration of benzoic acid (calories) = 10 cal

E_3 = Correction for additional heat release due to the combustion of firing wire and cotton thread (calories) = 20 gm.



OBSERVATION TABLE:

Time	Minute	Temperature difference per minute
Preliminary period		
Chief period Number of minutes during the chief period n = 8		
After period		

Uncorrected temperature rise ($T_n - T_0$) =

Add cooling correction = 0.0215°C

Corrected temperature rise = $(T_n - T_0) + 0.0215$

Heat liberated = energy equivalent of calorimeter (2230 cal) x corrected temperature rise = ... cal

Subtract nitrogen correction = 8.7 cal

Subtract thread correction = 21 cal

Subtract fuse wire correction = 20 cal

Subtract sulphur correction = 16 cal

Calorific value of the given sample = ...

CONCLUSIONS:



Ex 4 THEORY: The flash point is the lowest temperature at which a fuel gives off sufficient vapour to ignite momentarily when an external flame is applied. The fire point is the lowest temperature at which the vapour continues to burn for a specified period after ignition.

APPARATUS:

1. Open cup tester
2. Thermometer (0 – 300°C)
3. Sample of fuel/oil
4. Splinter sticks

DESCRIPTION OF THE EQUIPMENT:

This apparatus consists of a cylindrical cup of standard size. It is held in place in the metallic holder that is placed on a wire gauge and is heated by means of an electric heater housed inside the metallic holder.

A provision is made on the top edge of the cup to hold the thermometer in position. A standard filling mark has been scribed on the inner side of the cup and the sample oil is filled up to this mark. This apparatus is more accurate than PenskyMarton's closed cup and it gives sufficiently proclaimed accurate result for most of the practical purposes.

PROCEDURE:

1. Fill the cleaned open cup with the given sample of oil up to the standard filling mark of the cup
2. Insert the thermometer in the holder on the top edge of the cup. Make sure that the bulb of the thermometer is immersed in the oil and should not touch the metallic part.
3. Heat the sample of fuel / oil by means of an electric heater so that the sample of oil gives out vapour at the rate of 100 C per minute.
4. When the oil gives out vapours, start to introducing the glowing splinter (the flame should not touch the oil) and watch for any flash with firekering sound.
5. Blow out or expel the burnt vapour before introducing the next glowing splinter. This ensures that always fresh vapours alone is left over the surface of the oil and the test is carried out accurately.
6. Continue the process of heating and placing the glowing splinter at every ten degree of rise in temperature from the first flash till you hear the peak flickering sound and note the corresponding temperature as the flash point.
7. Continue the heating further after retaining the flash point and watch the fire point, which is noted when the body of the oil vapour ignites and continue to burn at least for five seconds.
8. Repeat the test twice or thrice with fresh sample of the same oil until the results are equal.
9. Tabulate the observations.

OBSERVATION TABLE:

SL No:	Temperature ($^{\circ}\text{C}$)	Observations
1		
2		
3		
4		

RESULT:

The flash and fire point test is carried out and the following oil / fuel properties are found.

The **Flash Point** of the given sample fuel / oil is =

The **Fire Point** of the given sample fuel / oil is =



Fig. 4: Pictorial view of a Cleveland open cup tester

CONCLUSIONS:



INSTRUCTION ITEM-4 (II 4)

Experiment No.	Name of the experiment	CO Congruence
EX 5	Performance test of a 4-stroke single cylinder diesel engine.	[CO4]

THEORY:

Measurement of brake power is one of the most important measurements in the test schedule of an engine. It involves the determination of the torque and the angular speed of the engine output shaft. The torque measuring device is called dynamometer. Fig shows the basic principle of a dynamometer. A rotor driven by the engine under test, is mechanically, hydraulically or electromagnetically coupled to a stator. For every revolution the shaft, the rotor periphery moves through a distance of $2\pi R$ against the coupling force, F .

So, Brake Power of engine is given by $= \pi D N (W-S) / (60 \times 1000)$ KW as calculated below.

APPARATUS USED:

1. Single Cylinder Diesel Engine Test Rig with Brake dynamometer
2. Stop Watch,
3. Hand Gloves
4. Digital Tachometer

FORMULATIONS:

Work done per revolution is, $= 2\pi RF$

Here, $F = (W - S)$

Where W is the load applied on the Dynamometer and S is the spring Balance reading, in N

The external moment or torque on the dynamometer is equal to $R.F = (W - S) \times R$ N-m

Therefore, Work done per revolution $= 2\pi (W - S) RF$ N-m

Work done per minute $= \pi DN(W-S)$ N-m

Brake power (BP) in KW $= \pi D N (W-S) / (60 \times 1000)$

Where, D = Brake Drum Diameter,

F = force acting on the brake drum,

N = RPM of the engine

W = load attached on the dynamometer

S = Reading of spring balance

PROCEDURE:

1. Observe all the safety precautions before starting the engine.
2. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
3. Set the dynamometer to zero load.
4. Run the engine till it attains the working temperature and steady state condition. Adjust the dynamometer load to obtain the desired engine speed. Record this engine speed and dynamometer reading.
5. Repeat steps 4, 5, and 6 for other remaining cylinders turn by turn and record the dynamometer readings for each cylinder.
6. Bring the dynamometer load to zero, disengage the dynamometer and stop the engine.
7. Do the necessary calculations.



OBSERVATIONS TABLE:

Trial No	Dia of Brake Drum, D (m)	Engine Rpm (N)	Load on Dynamometer, W (N)	Spring Balance Reading, S (N)	Fuel flow rate (Vf)
1					
2					
3					
4					
5					

CALCULATED TABLE:

Trial No	BP (kW)	BTE (%)	BSFC (kg/kWh)	IP	ITE (%)	ISFC (kg/kWh)	η_{mech} (%)
1							
2							
3							
4							
5							

CONCLUSIONS:



INSTRUCTION ITEM-5 (II 5)

Experiment No.	Name of the experiment	CO Congruence
EX 6	Performance test of a multi-cylinder petrol engine by MORSE method.	[CO5]

THEORY

The purpose of Morse Test is to obtain the approximate Indicated Power of a Multi-cylinder Engine. It consists of running the engine against a dynamometer at a particular speed, cutting out the firing of each cylinder in turn and noting the fall in BP each time while maintaining the speed constant. 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 to be 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.

APPARATUS USED:

1. Multi-Cylinder Petrol Engine Test Rig
2. Stop Watch,
3. Hand Gloves
4. Digital Tachometer.

FORMULATIONS:

- (i) Brake Power, $BP = WN / C$ KW;
Where $W = \text{Load on the Dynamometer Kg}$,
 $N = \text{rpm of the Engine}$, and $C = \text{Dynamometer Constant}$.
- (ii) Indicated Power (IP) of each Cylinders:
 $IP_1 = (BP_T - BP_{234})$ KW
 $IP_2 = (BP_T - BP_{134})$ KW
 $IP_3 = (BP_T - BP_{124})$ KW
 $IP_4 = (BP_T - BP_{123})$ KW
- (iii) Total IP of the Engine,
 $IP = (IP_1 + IP_2 + IP_3 + IP_4)$ KW
- (iv) Mechanical efficiency, $= BP_T / IP_T$

PROCEDURE:

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition. Adjust the dynamometer load to obtain the desired engine speed. Record this engine speed and dynamometer reading for the BP calculation.
4. Now cut off one cylinder. Short-circuiting its spark plug can do this.
5. Reduce the dynamometer load so as to restore the engine speed as at step 3. Record the dynamometer reading for BP calculation.



6. Connect the cut off cylinder and run the engine on all cylinders for a short time. This is necessary for the steady state conditions.
7. Repeat steps 4, 5, and 6 for other remaining cylinders turn by turn and record the dynamometer readings for each cylinder.
8. Bring the dynamometer load to zero, disengage the dynamometer and stop the engine.
9. Do the necessary calculations.

OBSERVATIONS:

Engine Speed, $N =$ rpm
No. of Cylinders, $n =$ Four
Calorific Value of Fuel, C.V. = KJ/Kg

OBSERVATIONS TABLE:

Sl. No.	Cylinders Working	Dynamometer Reading, (KW)	Brake Power, BP (KW)	IP of the cut off cylinder, (KW)
1.	1-2-3-4		*****	BPT =
2.	2-3-4		BP234=	IP1=
3.	1-3-4		BP134=	IP2=
4.	1-2-4		BP124=	IP3=
5.	1-2-3		BP123=	IP4=

RESULT:

Total IP of the Multi-Cylinder Petrol Engine by Morse Test, IPT = ... KW

CONCLUSIONS:

INSTRUCTION ITEM-6 (II 6)		
Experiment No.	Name of the experiment	CO Congruence
EX 7	Flue gas analysis using multi-gas analyser.	[CO6]

PRINCIPLE OF OPERATION:

Multi Gas Analyzer MN – 05 (4 gas version) is based on Infrared spectrometry technology with signal inputs from an electrochemical cell. Non-dispersive infrared measurement technique uses for CO (Carbon Monoxide), CO_2 (Carbon dioxide) and HC (Hydro Carbon) gases. Each individual gas absorbs infrared radiation at a specific rate. The amount of radiation absorbed can be used to calculate the concentration of sample gas.

Analyzer uses an electrochemical cell to measure oxygen concentration. It consists of two electrodes separated by an electrically conductive liquid or cell. The cell is mounted behind a polytetrafluorethene membrane through which oxygen can diffuse. The device therefore measures oxygen partial pressure. If a polarizing voltage is applied between the electrodes, the resultant current is proportional to the oxygen partial pressure.

RPM inductive pickup converts the magnetic field created by the current in the spark plug wire to a pulse that triggers an RPM measurement. To measure RPM using the pickup, attach the probe to any accessible spark plug wire.

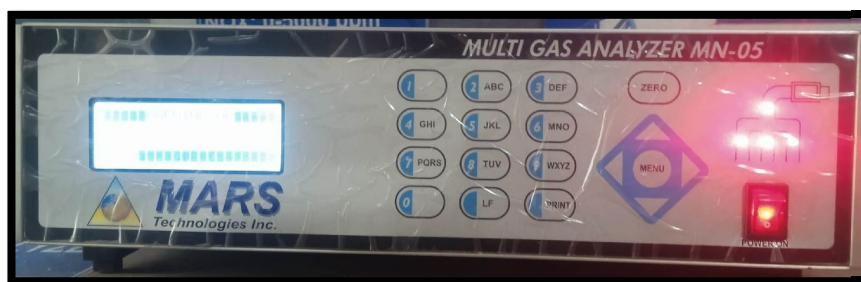


Fig. 5: Pictorial view of the multi-gas analyzer

Table 1: Technical specification of the analyser

Parameter	Specification
Instrument type	Microprocessor based multi-gas analyzer
Manufacturer	MARS Technologies INC.
Model	MN-05
Measurement principle	Electrochemical gas sensing (sensor dependent)
Display	Digital LCD display
Controller	Microcontroller-based system
Power supply	230 V AC, 50 Hz (12 V DC optional)
Interface	RS-232 / RS-485 (model configuration dependent)
Approximate dimensions	450 × 300 × 120 mm
Application	Combustion and exhaust gas analysis



Table 2: Gas measuring range of the analyser along with resolution data.

Gas Parameter	Measuring Range	Resolution
Carbon monoxide (CO)	0 – 9.99 % vol	0.001 % vol
Carbon dioxide (CO ₂)	0 – 20 % vol	0.01 % vol
Oxygen (O ₂)	0 – 25 % vol	0.1 % vol
Hydrocarbon (HC)	0 – 15000 ppm	1 ppm
Nitrogen oxides (NO _x)	0 – 5000 ppm	1 ppm

APPARATUS: Multi Gas Analyzer (mfg. MARS Technologies INC MN-05).

OBSERVATIONS:

SL No	Observations	Amount of constituent by %			
		% of CO ₂	% of O ₂	% of CO	HC (ppm)
1	First Sample				
2	Second Sample				
3	Third Sample				

PRECAUTIONS:

- Read the operating instructions carefully before installation
- Do not cover exhaust port as this will severely affect analyze operations
- This instrument is designated as class I equipment and should only be connected with its standard accessories.
- The instrument must be checked for good earth connection for protection against electric shock.

CONCLUSIONS: