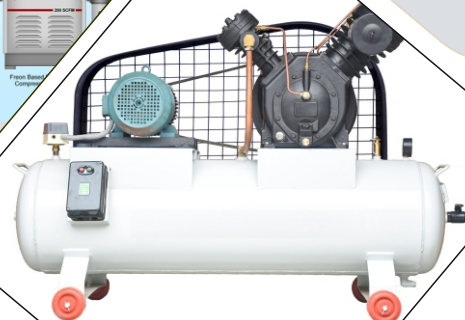
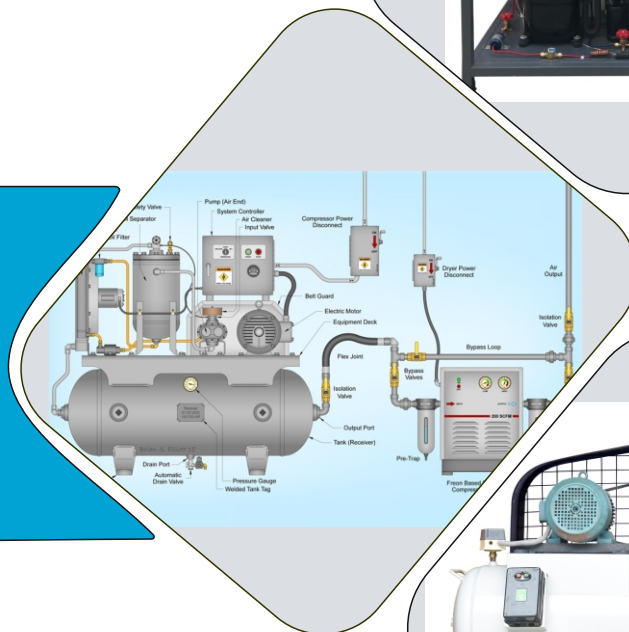


SCHEME :K

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Roll No.: _____ Year : 20 ____ 20 ____
Exam Seat No. : _____

LABORATORY MANUAL FOR POWER ENGINEERING (315371)



MECHANICAL ENGINEERING GROUP



**MAHARASHTRA STATE BOARD OF
TECHNICAL EDUCATION, MUMBAI
(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)**

VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION

To provide high-quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programs.

CORE VALUES

MSBTE believes in the following:

- Skill development in line with industry requirements.
- Industry readiness and improved employability of Diploma holders.
- Synergistic relationship with industry.
- Collective and Cooperative development of all stake holders.
- Technological interventions in societal development.
- Access to uniform quality technical education.

A Practical Manual

for

Power Engineering

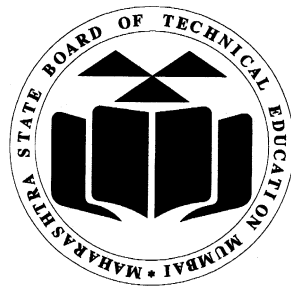
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Semester– (V)

“K-SCHEME”

(Diploma in Mechanical Engineering)

(ME)



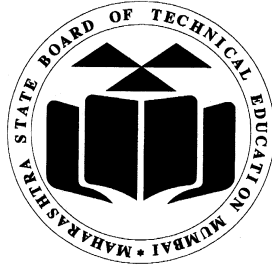
Maharashtra State

Board of Technical Education, Mumbai

(Autonomous) (ISO-21001:2018) (ISO/IEC 27001:2013)



Maharashtra State Board of Technical Education, Mumbai
(Autonomous) (ISO:21001: 2018) (ISO/IEC 27001:2013)
4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai – 400051,
(Printed on July 2025)



Maharashtra State Board of Technical Education, Mumbai

Certificate

This is to certify that Mr. /Ms.....
Roll No. of Fifth semester of Diploma in
..... of Institute
.....
(Code:) has completed the term work satisfactorily in course **Power Engineering
(315371)** for the academic year 20.....to 20..... as prescribed in the
curriculum.

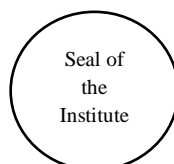
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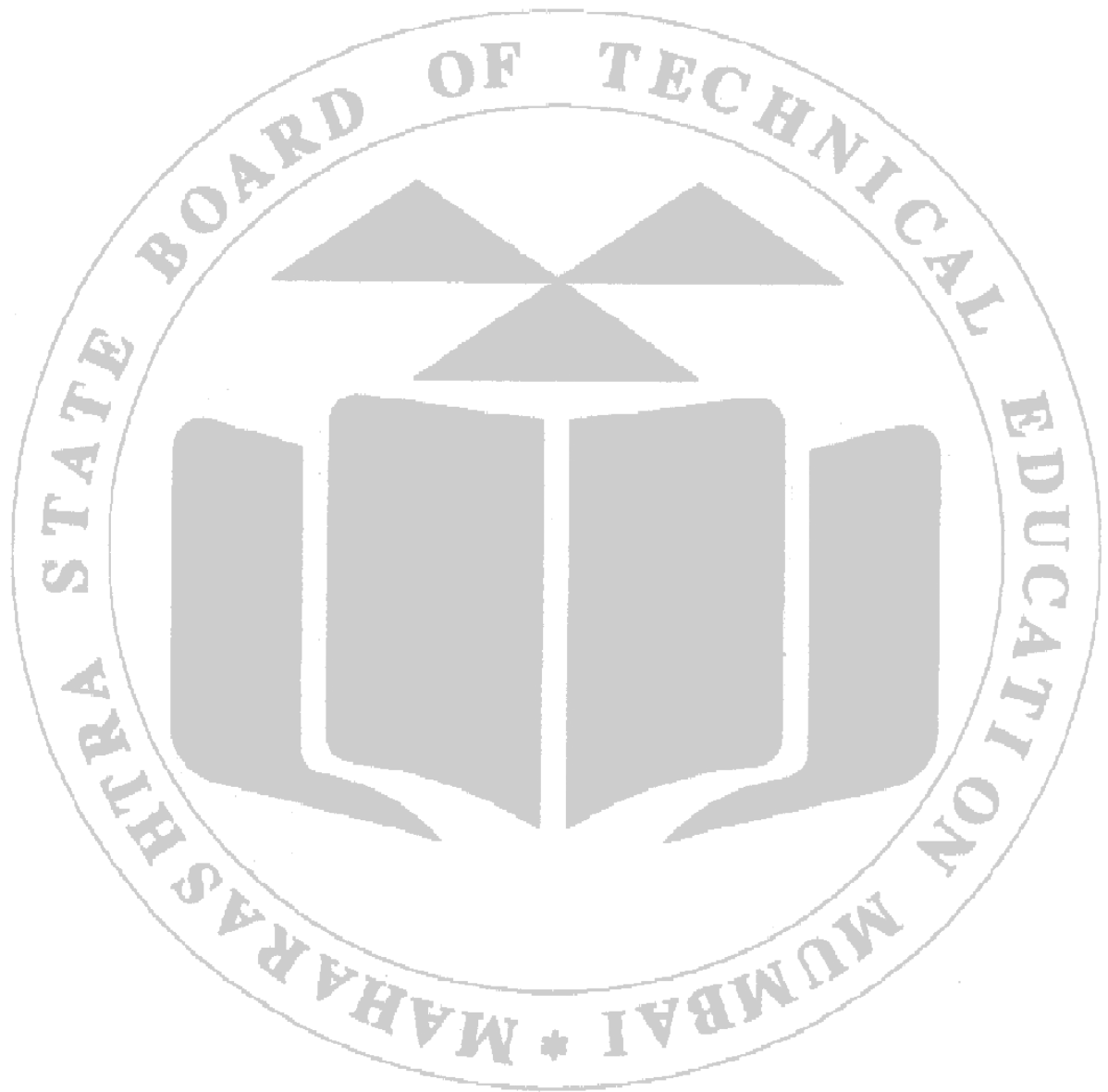
Date:..... Exam Seat No:.....

Course Teacher

Head of the Department

Principal





Preface

The primary focus of engineering laboratory/ field work in the technical education system is to develop the much-needed industry-relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curriculum for engineering diploma programs with National Education Policy 2020 (NEP2020) and outcome-based education as the focus, and accordingly, a relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work, making each teacher, instructor, and student realize that every minute of the laboratory time needs to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a vehicle to develop this industry-identified competency in every student. The practical skills are difficult to develop through 'chalk and duster' activity in the classroom situation. Accordingly, the 'K'scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age-old practice of conducting a practical to 'verify the theory' (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers, and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical.

Every practical in this manual begins by identifying the practical significance industry industry-expected outcome competency, course-level learning outcomes, and laboratory learning outcomes, which serve as a key focal point for doing the practical. The students will then become aware of the skills they will achieve through the procedure shown there and the necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources so that the students follow the procedures and precautions systematically, ensuring the achievement of outcomes for the students.

Power engineering plays a critical role in equipping mechanical diploma engineers with the essential knowledge and practical skills needed to operate, maintain, and test various power engineering systems used in industrial applications. This course forms a critical pillar of mechanical engineering, empowering students with the ability to test, analyze, and maintain power engineering systems crucial for a variety of industrial and commercial applications. In recognition of this, each practical is developed to build fundamental understanding and practical exposure to power engineering devices. Encourage skill development in handling, testing, assembling, and troubleshooting critical components of refrigeration and air conditioning systems, I.C. engines, and air compressors. Familiarize students with performance measurement and analysis of these systems.

Although all care has been taken to check for mistakes in this laboratory manual, it is impossible to claim perfection, especially as this is the first edition. Any such errors and suggestions for improvement can be brought to our notice and are highly welcome.

Lab Manual Development Team

Programme Outcomes (POs) to be achieved through practicals of this course

Following POs are expected to be achieved through the practical of the (Thermal Engineering) course.

PO1. Basic and discipline-specific knowledge: Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the mechanical engineering problems.

PO 2. Problem analysis: Identify and analyze well-defined mechanical engineering problems using codified standard methods.

PO 3. Design/ development of solutions: Design solutions for well-defined technical problems and assist with the design of system components or processes to meet specified needs in mechanical engineering.

PO 4. Engineering Tools, Experimentation and Testing: Apply modern mechanical engineering tools and appropriate techniques to conduct standard tests and measurements.

PO 5. Engineering practices for society, sustainability, and environment: Apply appropriate technology in context of society, sustainability, environment, and ethical practices.

PO 6. Project Management: Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

PO 7. Life-long learning: Ability to analyze individual needs and engage in updating in the context of technological changes in mechanical engineering.

List of Industry-Relevant Skills

The following industry-relevant skills of the competency 'Maintain power engineering and refrigeration devices for various industrial / field applications using relevant knowledge & skills related to power engineering' are expected to be developed in students by undertaking the practical of this laboratory manual.

1. Maintain refrigeration and air conditioning devices.
2. Ability to analyze and interpret refrigeration system performance.
3. Select the proper tools for dismantling/assembling refrigerated devices.
4. Measure air properties of conditioned air, such as dry bulb temperature, wet bulb temperature, using a sling psychrometer.
5. Understand parameters of IC engine performance testing.
6. Analyze engine performance based on power output and related curves.
7. Assess performance of the I.C. engine using exhaust gas analyzer
8. Assess condition and performance of the I. C. engine using diagnostic tools.
9. Select and maintain reciprocating air compressor for the desired industrial application.
10. Ability to assess and optimize the performance of compressed air systems and HVAC systems for energy efficiency.

Practical- Course Outcome Matrix**Course Outcomes (COs)**

CO1 - Assess the performance of given refrigeration systems.

CO2 - Measure the cooling capacity of air-conditioning systems.

CO3 - Carryout test for the performance of an I.C. engine.

CO4 - Analyze the performance of air compressor.

CO5 -Use the knowledge of energy saving in air compressor & refrigeration and air-conditioning systems.

Sr. No.	Laboratory Practical Titles	CO 1	CO 2	CO 3	CO 4	CO 5
1	Trace the flow of refrigerant through various components of the domestic refrigerator.	√	-	-	-	-
2	*Test on vapor compression refrigeration test rig.	√	-	-	-	-
3	Assemble / Dismantle various components of water cooler.	√	-	-	-	-
4	*Use of sling psychrometer.	-	√	-	-	-
5	Assemble / Dismantle various components of window air conditioner.	-	√	-	-	-
6	*Test on window air conditioner.	-	√	-	-	-
7	Demonstration of split air conditioner.	-	√	-	-	-
8	Test on air conditioning test rig.	-	√	-	-	-
9	*Demonstration of I.C. engine test rig.	-	-	√	-	-
10	*Test on I.C. engine test rig Part – I	-	-	√	-	-
11	*Test on I.C. engine test rig Part – II	-	-	√	-	-
12	*Morse Test on I.C. engine test rig.	-	-	√	-	-
13	Use of exhaust gas analyzer for S.I. engine.	-	-	√	-	-
14	Use of exhaust gas analyzer for C.I. engine.	-	-	√	-	-
15	Diagnosis test on I.C. engine using engine control unit.	-	-	√	-	-
16	*Test on two-stage reciprocating air compressor Part I	-	-	-	√	-
17	*Test on two-stage reciprocating air compressor Part I	-	-	-	√	-
18	Losses in the compressed air system.	-	-	-	-	√
19	*Energy saving in air-conditioning system.	-	-	-	-	√

Guidelines to Teachers

1. A teacher needs to ensure that a dated log book for the whole semester, apart from the laboratory manual, is maintained by every student, which s/he have to submit for assessment to the teacher in the next practical session.
2. There will be two sheets of blank pages after every practical for the student to report other matters (if any), which are not mentioned in the printed practical.
3. For difficult practical's if required, a teacher could provide a demonstration of the practical, emphasizing the skills which the student should achieve.
4. Teachers should give opportunity to students for hands-on after the demonstration.
5. Assess the skill achievement of the students and COs of each unit.
6. One or two questions ought to be added in each practical for different batches. For this teacher can maintain various practical-related question banks for each course.
7. If some repetitive information, like data sheet, use of software tools, etc., has to be provided for effective attainment of practical outcomes, they can be incorporated in the Appendix.
8. For effective implementation and attainment of practical outcomes, teachers ought to ensure that, at the beginning itself of each practical, students must read through the complete write-up of that practical sheet.
9. During practical, ensure that each student gets a chance and takes an active part in taking observations/readings and performing practical.
10. Teacher ought to assess the performance of students continuously according to the MSBTE guidelines
11. Experimental setups proposed are guidelines. Teacher can do better and give his valuable feedback to MSBTE on further improvements in the lab manual.
12. Teachers shall use any suitable demo/open-source simulation software available on the internet.

Instructions for Students

1. For incidental writing on the day of each practical session, every student should maintain a dated log book for the whole semester, apart from this laboratory manual, which s/he has to submit for assessment to the teacher in the next practical session.
2. For effective implementation and attainment of practical outcomes, at the beginning itself of each practical, students need to read through the complete write-up, including the practical-related questions and assessment scheme of that practical sheet.
3. Students ought to refer to the data books, IS codes, Safety norms, Technical Manuals, etc.
4. Students should not hesitate to ask about any difficulties they face during the conduct of practical.
5. Students are expected to perform the experiments in groups (as applicable), whereas calculations shall be made independently.

Content Page**List of Practical and Progressive Assessment Sheet**

Sr. No	Laboratory Practical Titles	Page No.	Date of performance	Date of submission	FA- PR marks (25)	Dated sign. of teacher	Remarks (if any)
1	Trace the flow of refrigerant through various components of the domestic refrigerator.	01					
2	*Test on vapor compression refrigeration test rig.	09					
3	Assemble / Dismantle various components of water cooler.	19					
4	*Use of sling psychrometer.	25					
5	Assemble / Dismantle various components of window air conditioner.	31					
6	*Test on window air conditioner.	38					
7	Demonstration of split air conditioner.	45					
8	Test on air conditioning test rig.	51					
9	*Demonstration of I.C. engine test rig.	59					
10	*Test on I.C. engine test rig Part – I	69					
11	*Test on I.C. engine test rig Part – II	79					
12	*Morse Test on I.C. engine test rig.	92					
13	Use of exhaust gas analyzer for S.I. engine.	101					
14	Use of exhaust gas analyzer for C.I. engine.	109					

Sr. No	Laboratory Practical Titles	Page No.	Date of performance	Date of submission	FA- PR marks (25)	Dated sign. of teacher	Remarks (if any)
15	Diagnosis test on I.C. engine using engine control unit.	117					
16	*Test on two-stage reciprocating air compressor Part I	124					
17	*Test on two-stage reciprocating air compressor Part II	131					
18	Losses in the compressed air system.	141					
19	*Energy saving in air-conditioning system.	146					
Total							

Note: To be transferred to Proforma of CIAAN-2023.

A suggestive list of LLOs is given in the above table. More such LLOs can be added to attain the COs and competency. A judicious mix of a minimum 12 or more practical's need to be performed, out of which, the practical's marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.

Practical No. 1: Trace the flow of refrigerant through various components of the domestic refrigerator.

I. Practical Significance

This practical will help the students to understand the internal functioning of a domestic refrigerator, which is a critical appliance in every household. It allows them to visually and physically trace the path taken by the refrigerant as it flows through the Vapor Compression Cycle (VCC). Understanding this flow is vital for those entering fields such as refrigeration and air conditioning, appliance repair, and HVAC (Heating, Ventilation, and Air Conditioning) industries. It also helps in identifying issues like refrigerant leaks, compressor failure, or inefficient cooling, which are common in both domestic and industrial refrigeration systems. By completing this practical, students gain hands-on knowledge of real-world equipment, improving their technical proficiency and understanding of energy systems.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer –

- Maintain refrigeration and air conditioning devices.
- Detect faults or inefficiencies in the system
- Communicate findings effectively with diagrams and technical language.

III. Course Level Learning Outcome (CO)

CO1- Assess the performance of given refrigeration systems.

IV. Laboratory Learning Outcome(s)

- Prepare a schematic diagram showing the various components of a domestic refrigerator.
- Prepare a sketch of the flow path of refrigerant

V. Relative Affective Domain Related Outcome(s)

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Handling equipment responsibly and reporting observations honestly.
- Follow ethical Practices.

VI. Minimum Theoretical Background

Before conducting this practical, students should:

- Know the construction and working of the refrigeration system.
- Identify various subassemblies of refrigeration and refrigeration systems.
- Identify the accessories of refrigeration and the refrigeration system.
- Know the Vapor Compression Cycle (VCC) and be able to draw on P-H and T-S diagrams.
- Identify the parts of VCRS
- Understanding how pressure and phase changes affect temperature.

A domestic refrigerator is a household appliance used to preserve food for short periods by maintaining a cold environment through refrigeration. It consists of a metal cabinet with a sealed refrigerating unit that operates on the Vapor Compression Cycle (VCC). In this cycle, a refrigerant gas is compressed and condensed into a high-pressure liquid in the condenser coils, where it releases heat to the surrounding air. The liquid then passes through an expansion valve, cooling rapidly as it enters the evaporator coils inside the fridge and freezer, where it evaporates and absorbs heat, thus cooling the interior. This cycle repeats continuously to maintain the desired temperature. Modern refrigerators typically use HFC-134a (1,1,1,2-Tetrafluoroethane) as a refrigerant, which is safer for the ozone layer compared to older Freon-based gases. The main purpose of refrigeration is to slow down bacterial activity in food, thereby extending its freshness. Temperature regulation is managed by a thermostat, a closed-loop control device that senses and maintains the internal temperature near a set point by controlling the cooling process.

VII. Experimental setup

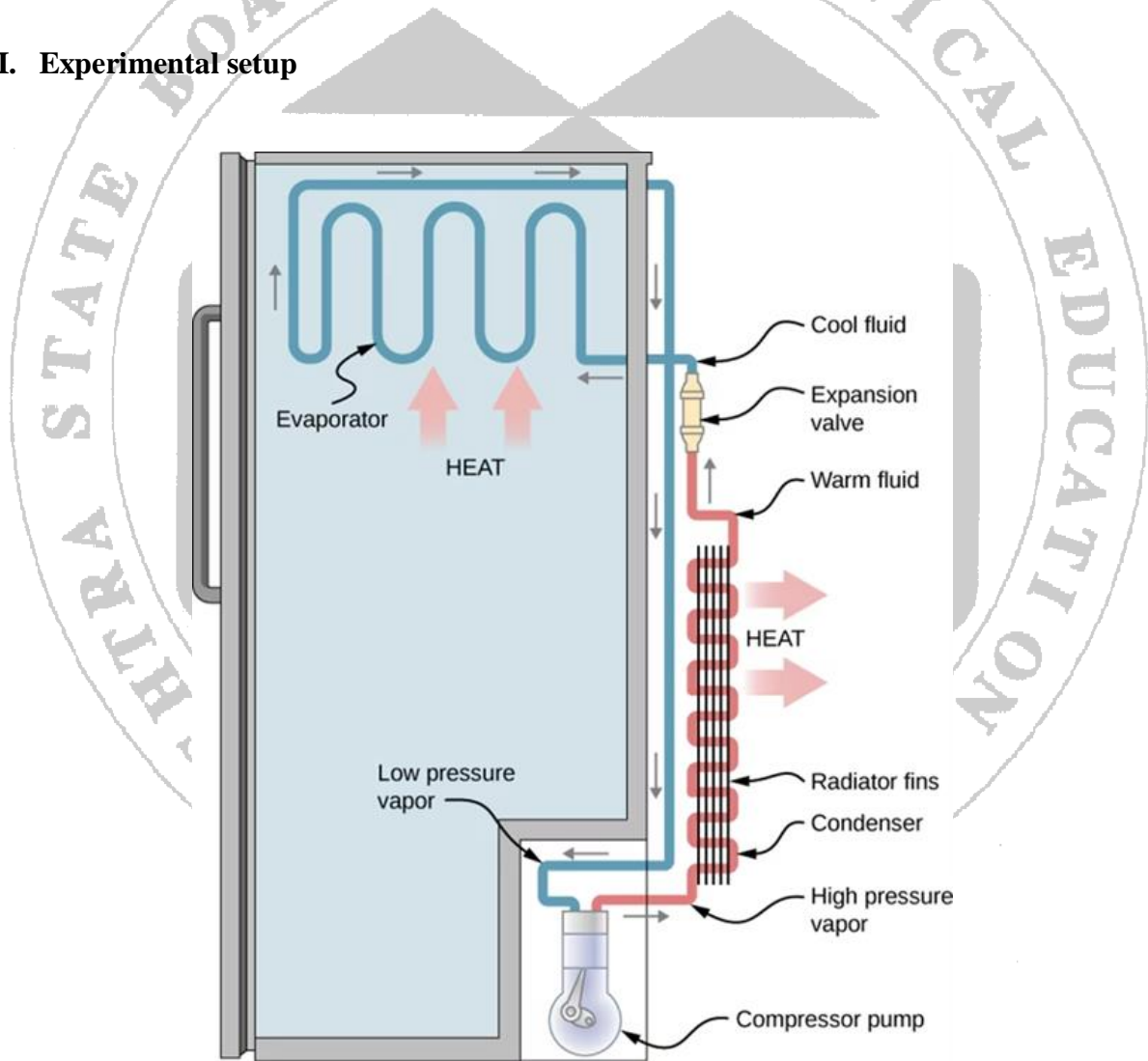


Figure 1.1 Domestic refrigerator

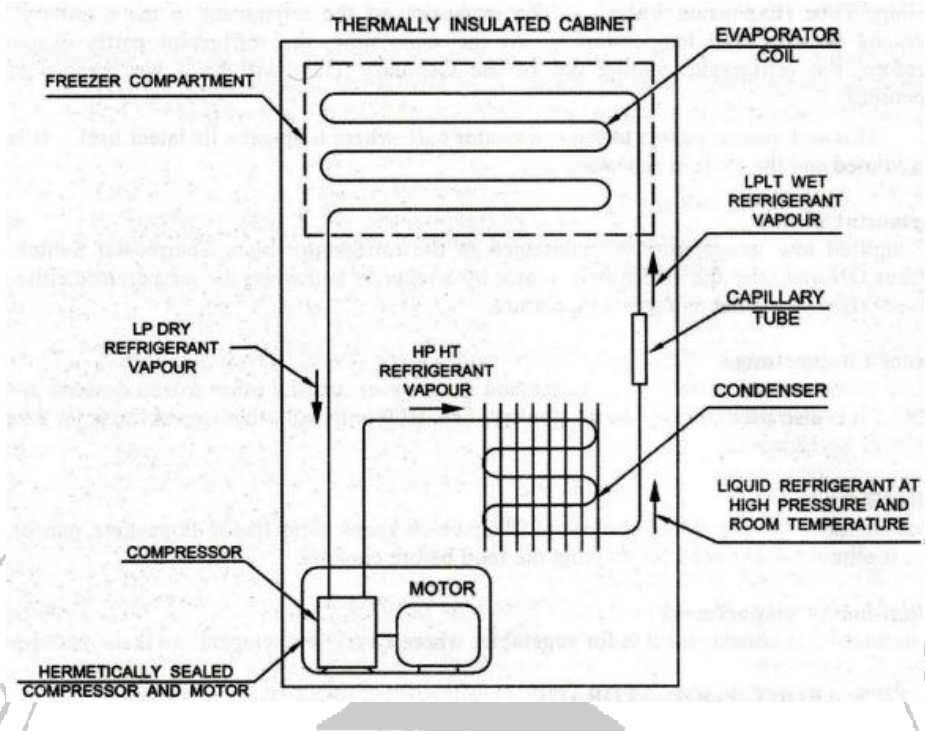


Figure 1.2 Line diagram of Domestic refrigerator



Figure 1.3 Actual Cut-section of household refrigerator representing PUF insulating back panel, Condenser coil.



Figure 1.4 Actual Cut-section of a household refrigerator representing Evaporator

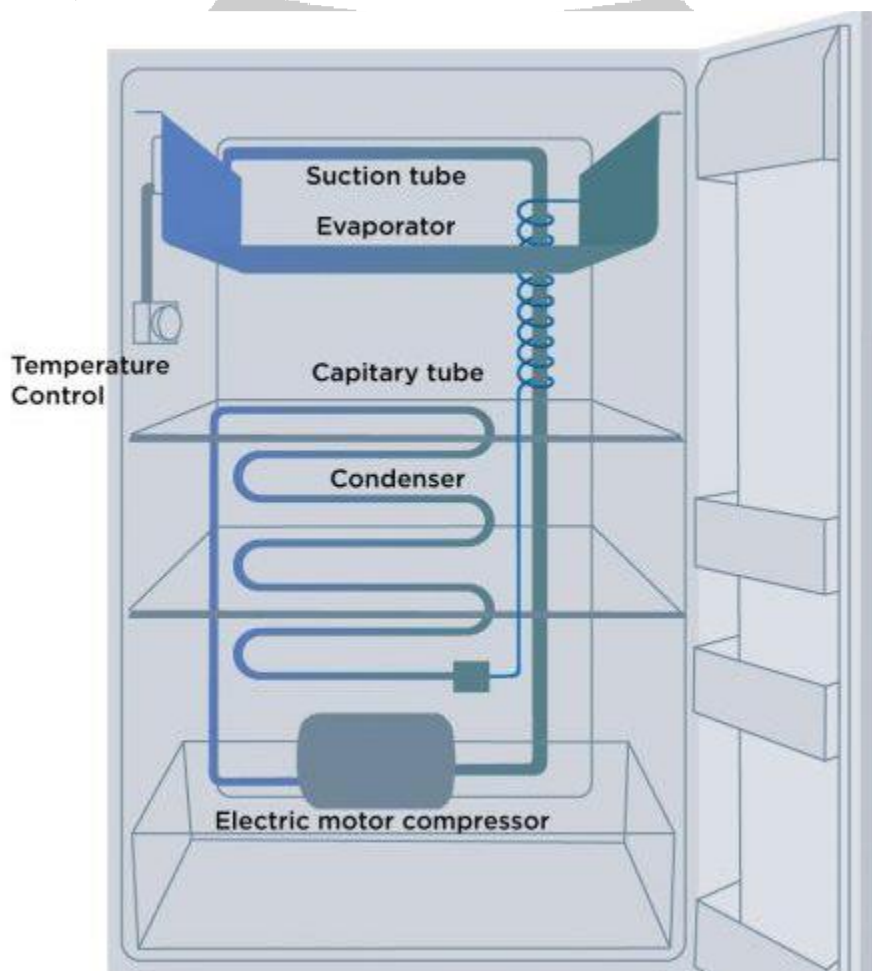


Figure 1.5 Components of Domestic refrigerator

VIII. Required Resources /Apparatus/Equipment with specifications

S. No.	Parameters / Name of the resource	Suggested Broad Specification	Quantity
1	Domestic Refrigerator	An actual working or scrap unit of a domestic refrigerator of a minimum of 165 liters, having all the necessary parts	01

IX. Precautions to be Followed

- Ensure that the refrigerator is connected to with proper electric power supply.
- Ensure that the refrigerator door is tightly closed.
- Avoid improper handling.
- Use safety shoes.
- Use tools safely.

X. Procedure

1. Select the domestic refrigerator model for demonstration.
2. Observe the model selected for study purposes.
3. Explain the working principle of a domestic refrigerator.
4. Identify and locate the major components.
5. Observe the location of each component.
6. State the functions of each component of a domestic refrigerator
7. Locate the refrigerant tubes connecting different parts and trace the path of the refrigerant.
8. Using arrows or labels, mark the direction of refrigerant flow through all components.

XI. Observations and calculations

Draw the labeled diagram of the domestic refrigerator showing the path of refrigerant

Complete the following observation table

Sr. No	Particulars/ Component	Type& Make	Function	Refrigerant State	Pressure	Process
1	Compressor					
2	Condenser					
3	Expansion Valve					
4	Evaporator					

XII. Results

XIII. Interpretation of Results

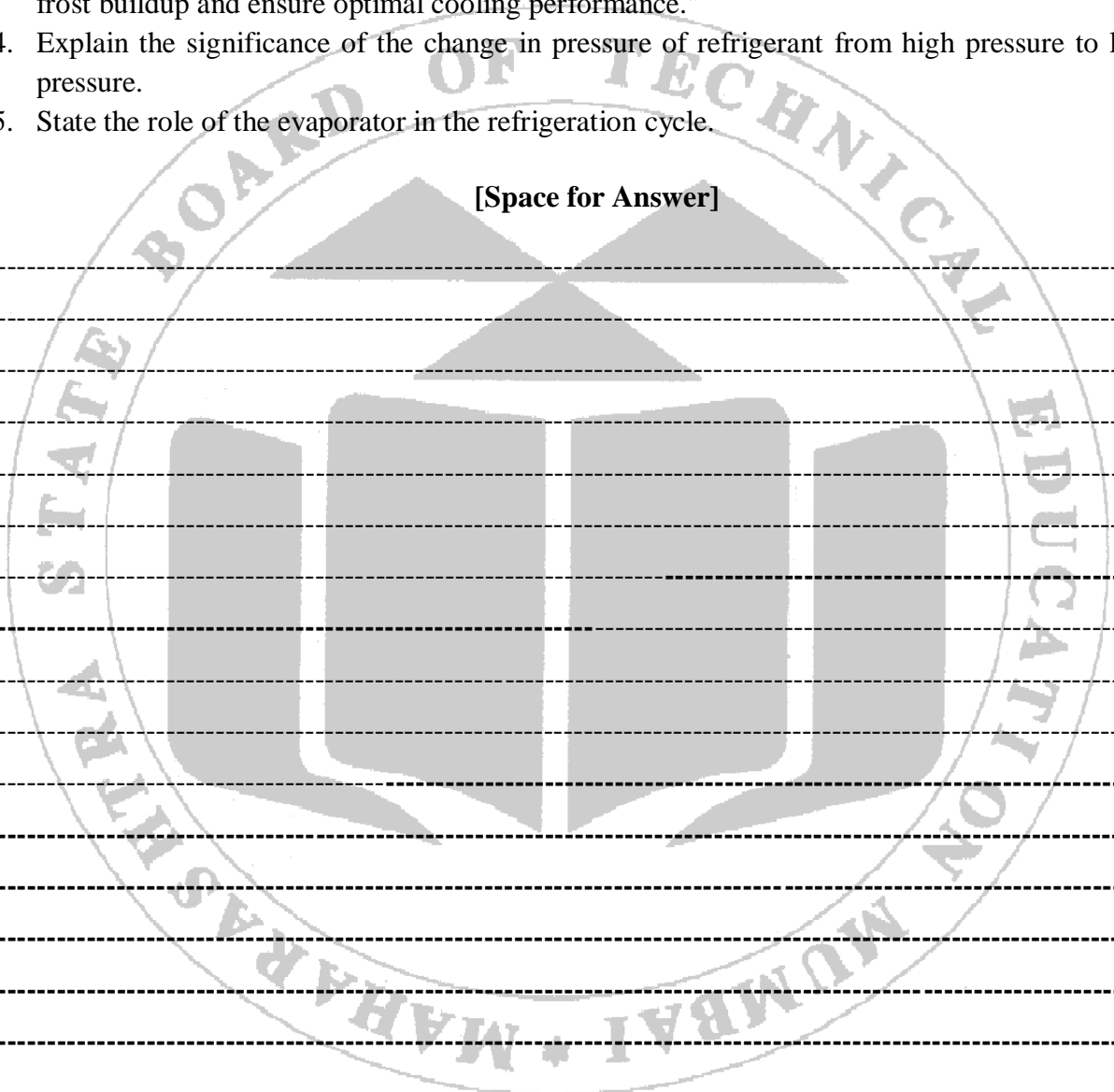
XIV. Conclusions and Recommendations

XV. Practical Related Questions

Note: Below given are a few sample questions for reference. Teachers must design more such questions to ensure the achievement of the identified CO.

1. Enlist the components of a domestic refrigerator with their material
2. State the significance of the capillary tube as a throttling device in maintaining pressure control and efficient refrigeration operation.
3. Illustrate the importance of regularly inspecting and maintaining the evaporator to prevent frost buildup and ensure optimal cooling performance."
4. Explain the significance of the change in pressure of refrigerant from high pressure to low pressure.
5. State the role of the evaporator in the refrigeration cycle.

[Space for Answer]



A series of horizontal dashed lines provided for writing the answers to the questions above.

XVI. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=XO2PBDMEHfs&list=PLJrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=8
- https://www.youtube.com/watch?v=urFrdSAJmyM&list=PLJrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=9
- <https://www.youtube.com/watch?v=RR-3Uq--4Oo>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Component Identification Accuracy	20%
2	Understanding of Flow Direction	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 2: Test on vapor compression refrigeration test rig

I. Practical Significance

The vapor compression refrigeration system is the most commonly used cycle in domestic, commercial, and industrial applications. Understanding its performance is crucial for engineers working in HVAC (Heating, Ventilation, and Air Conditioning), automotive, food preservation, and industrial cooling fields. Determining the Coefficient of Performance (COP) helps evaluate the system's energy efficiency, enabling optimization and energy savings. Practical Significance: The vapor compression refrigeration cycle includes a hermetically sealed compressor, condenser, expansion devices, and evaporator. The working medium, called a refrigerant, is used in vapor form to produce the cooling effect. The refrigerating effect is the amount of cooling generated by the system, which requires energy. Vapor-compression refrigeration, or vapor-compression refrigeration system (VCRS), involves phase changes of the refrigerant and is among the most common methods for air conditioning in buildings and automobiles. The coefficient of performance is the ratio of the refrigerating effect to the work done by the compressor.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer –

- Ability to analyze and interpret refrigeration system performance.
- Capability to handle instrumentation and troubleshoot refrigeration systems.
- Application of thermodynamics and heat transfer in practical setups.

III. Course Level Learning Outcome (CO)

CO1 - Assess the performance of given refrigeration systems.

IV. Laboratory Learning Outcome(s)

- Perform the test using a vapor compression refrigeration test rig to measure the various parameters, like temperature, pressure, etc.
- Calculate the COP of the system.

V. Relative Affective Domain Related Outcome(s)

- Follow safety practices.
- Practice good housekeeping.
- Work as a leader / a team member.
- Follow ethical Practices.
- Promote teamwork and communication during group experiments.

VI. Minimum Theoretical Background

A vapor compression refrigeration (VCR) system is one of the most widely used refrigeration cycles. It is used in refrigerators, air conditioners, and heat pumps. The vapor compression cycle operates based on the phase change of a refrigerant, which absorbs heat from a low-temperature area and releases it to a high-temperature area. The cycle involves compression, condensation, expansion, and evaporation of the refrigerant. The theoretical analysis of the VCR cycle involves assessing the system's thermodynamic performance. In an ideal cycle, the process includes isentropic compression, isobaric heat rejection in the condenser, isenthalpic expansion in the expansion device, and isobaric heat absorption in the evaporator. During testing, various parameters are measured, including temperatures and pressures at key points, the power used by the compressor, and the refrigerant flow rate. These values are used to determine the refrigeration effect, work input, and the system's coefficient of performance (COP). The COP is a vital measure of system efficiency and is defined as the ratio of the refrigeration effect to the work input.

VII. Experimental setup



Figure 2.1 Vapor compression refrigeration Test rig

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Vapor compression refrigeration Test rig	Compressor: Hermetically sealed compressor having cooling capacity of (1/4 ton). Evaporator: Air-cooled / Plate-type heat exchanger. Condenser: Air-cooled finned tube type or water-cooled shell and tube type. Expansion Device: Capillary tube or thermostatic expansion valve (TEV).	1

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
		Pressure Gauges:2 Nos. (High pressure & Low pressure) Range: 0–300 psi (HP), 0–150 psi (LP). Rota meter: For measuring the flow rate of liquid refrigerant. Capacity: 0 to 100 LPH.	

IX. Precautions to be Followed

- Ensure there is no leakage of refrigerant before starting the experiment.
- Never operate the unit, keeping the condenser fan switched off.
- Before taking any readings, allow the system to run for at least 5–10 minutes so that it reaches a steady-state operating condition.
- Run the system under recommended conditions only — avoid exceeding specified pressure and temperature limits.
- Start and shut down the compressor gradually.
- Do not block airflow to the condenser or evaporator coils.
- Do not touch electrical connections or the wattmeter with wet hands.

X. Procedure

1. Refer to the manual supplied by the manufacturer and identify different components and controls of the refrigeration test rig.
2. Select a capillary tube or thermostatic expansion valve (TEV) by using manually operated shut-off valves.
3. Fill three-fourths of evaporator tank with water
4. Switch on the condenser fan, and after two minutes, switch on the compressor.
5. Watch the thermometer reading of the water in the evaporator; it will go on reducing.
6. As the temperature of the Water reaches around 20°C, switch on the heater unit.
7. Adjust the dimmer stat of the heater such that the temperature of the water does not further fall.
8. Run the unit till steady state is reached, i.e. temperature of the water remains constant.
9. Read the condenser & evaporator pressure gauges & enter them in the observation table.
10. Note the temperature reading on the digital temperature indicator by turning the knob.
11. Measure the time taken for 10 revolutions of the energy meter disc of the compressor and heater (i.e., T_c & T_h). (In case of an electronic energy meter, measure the time taken for 10 pulses.)
12. Switch off the unit in the following order: heater, compressor, and condenser fan.

XI. Observations and calculations

Observations:

Sr. No.	Description	Symbol	Unit	Reading
1	Evaporator pressure	P_e	bar	
2	Condenser pressure	P_c	bar	
3	Evaporator Inlet Temperature	T_{ei}	$^{\circ}C$	
4	Evaporator Outlet Temperature	T_{eo}	$^{\circ}C$	
5	Condenser Inlet Temperature	t_{ci}	$^{\circ}C$	
6	Condenser Outlet Temperature	t_{co}	$^{\circ}C$	
7	Time for 10 revolutions of pulses of energy meter of compressor	T_c	sec	
8	Time for 10 revolutions of pulses of Energy meter of Heater	T_h	sec	
9	Energy meter constant for Heater	N_h	(rev/kWh)	
10	Energy meter constant for Compressor	N_c	(rev/kWh)	

Calculations:

a. Carnot COP:

Read from the refrigerant property table and fill the following table for the calculation of Carnot COP

Sr. No.	Description
1	T_L = Saturation temperature corresponding to $P_e = \dots\dots\dots + 273 = \dots\dots\dots K$
2	T_H = Saturation temperature corresponding to $P_c = \dots\dots\dots + 273 = \dots\dots\dots K$

$$\begin{aligned} \text{Carnot COP} &= T_L / (T_H - T_L) \\ &= \dots\dots\dots \\ &= \dots\dots\dots \end{aligned}$$

b. Theoretical COP –

Plot the cycles on P-h chart for the refrigerant used and fill in the table given below for Calculation of theoretical COP

Sr. No.	Description	Symbol	Reading in kJ/kg
1	Enthalpy at the evaporator inlet	h _{ei}	
2	Enthalpy at the evaporator outlet	h _{eo}	
3	Enthalpy at the condenser inlet	h _{ci}	
4	Enthalpy at the condenser outlet	h _{co}	

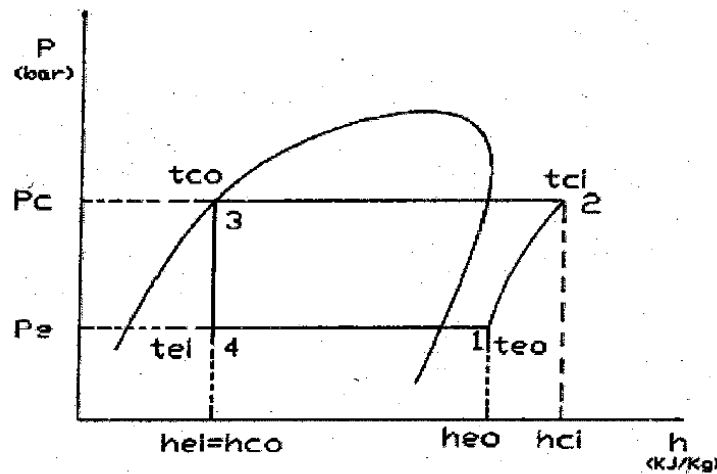


Figure 2.2 P-H Diagram for VCR cycle

Theoretical COP

= (Theoretical Refrigerating Effect) / (Theoretical Compressor Work)

= (h_{eo} - h_{ei}) / (h_{ci} - h_{eo})

= (..... -) / (..... -)

=

c. Actual COP –

Actual COP = (Actual Refrigerating Effect) / (Actual work supplied to compressor)

Here, actual Refrigerating Effect = Heat produced by the heater

R.E. = (10 / N_h) x (3600 / T_h) kW

R.E. =

R.E. = kW

If the heater is not used

Refrigeration Effect = $\{M_w * C_{pw} * (T_2 - T_1)\}$ / time required for cooling from initial to final water temperature

Where T_1 = Initial temperature of water

T_2 = Final temperature of water

M_w = mass of water in evaporator

Actual energy supplied to the compressor

$$W_c = (10 / N_c) \times (3600 / T_h) \text{ kW}$$

$$= (10 / \dots) \times (3600 / \dots) \text{ kW}$$

$$= \dots \text{ kW}$$

Actual COP = Refrigeration Effect / Actual energy supplied to compressor

$$= R.E. / W_c$$

$$= \dots / \dots$$

$$= \dots$$

XII. Results

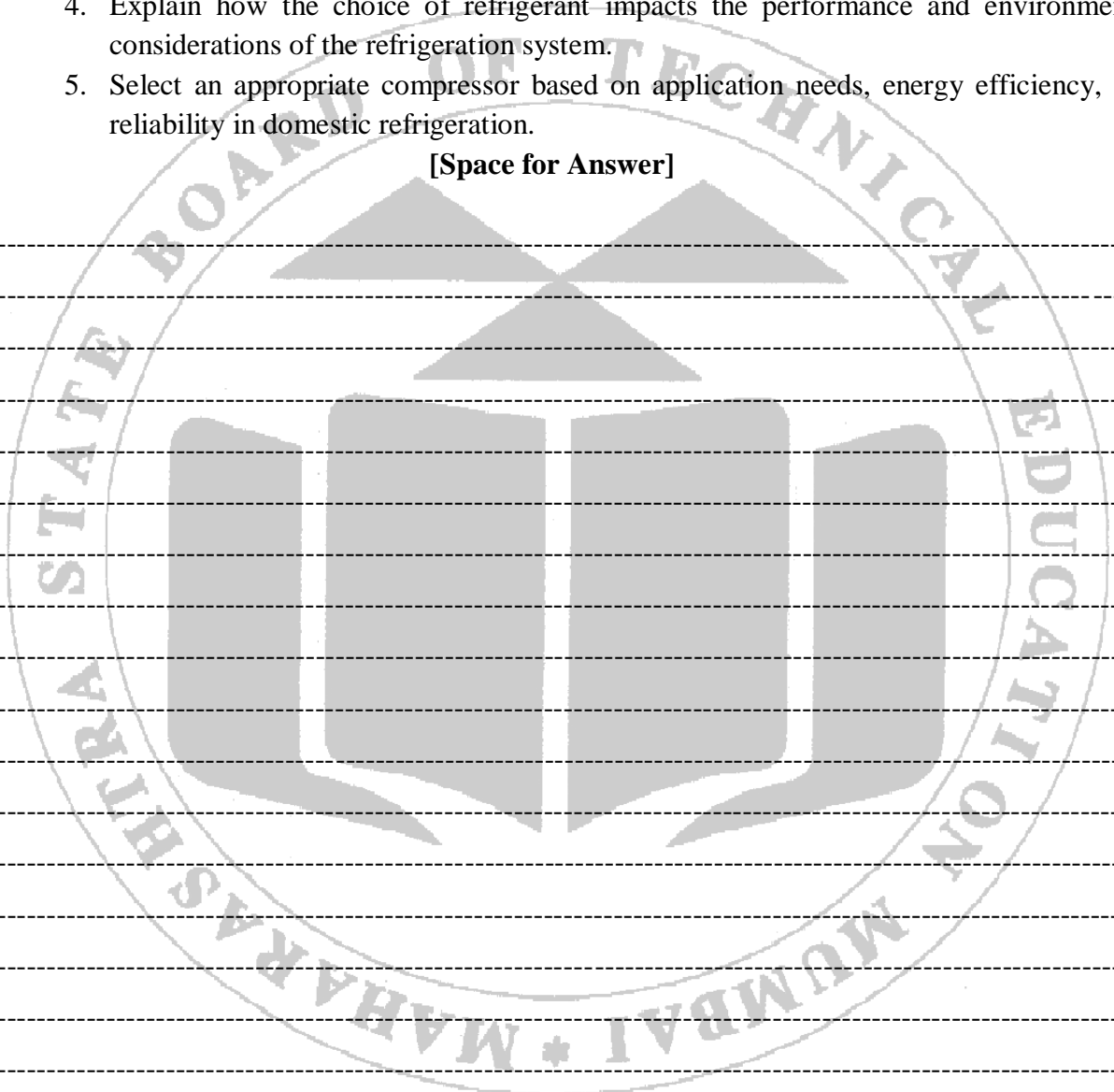
XIII. Interpretation of Results

XIV. Conclusions and Recommendations

XV. Practical Related Questions

1. Trace and label the path of refrigerant through all components: compressor, condenser, expansion device, and evaporator in a refrigeration unit.
2. Enlist an instrument to measure the flow rate of the refrigerant and the power consumption
3. Explain how the enthalpy at different points in the system is used to determine the efficiency and performance of the refrigeration cycle.
4. Explain how the choice of refrigerant impacts the performance and environmental considerations of the refrigeration system.
5. Select an appropriate compressor based on application needs, energy efficiency, and reliability in domestic refrigeration.

[Space for Answer]



A large watermark of the Maharashtra State Board of Technical Education logo is centered on the page. The logo consists of a circular emblem with a book and a lamp in the center, surrounded by the text 'MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION MUMBAI'. Below the logo, there are several horizontal dashed lines intended for writing the answer to the questions.

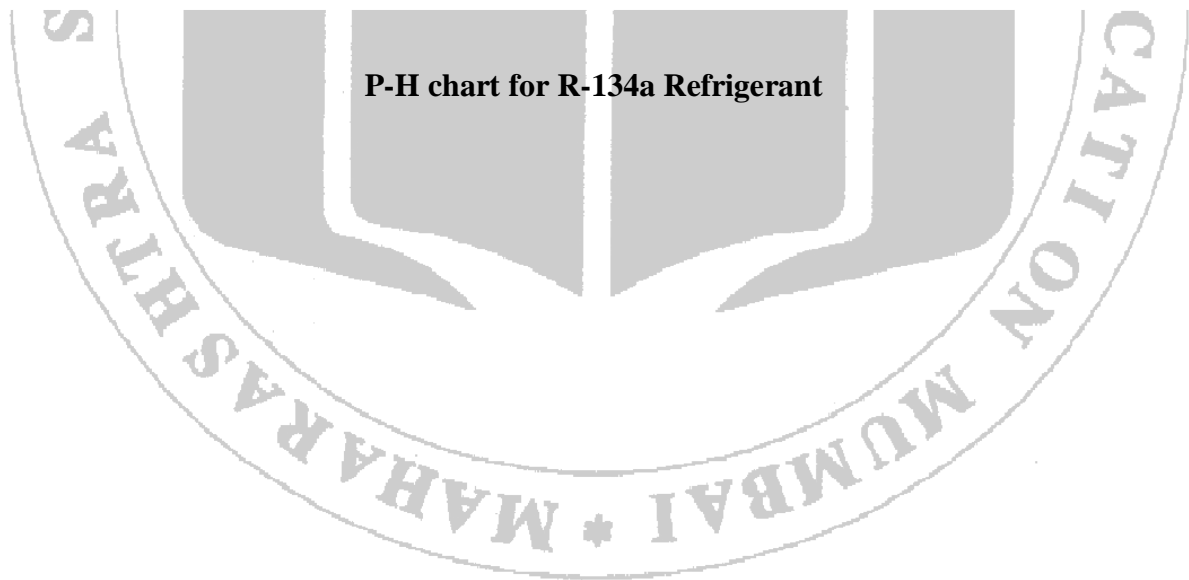
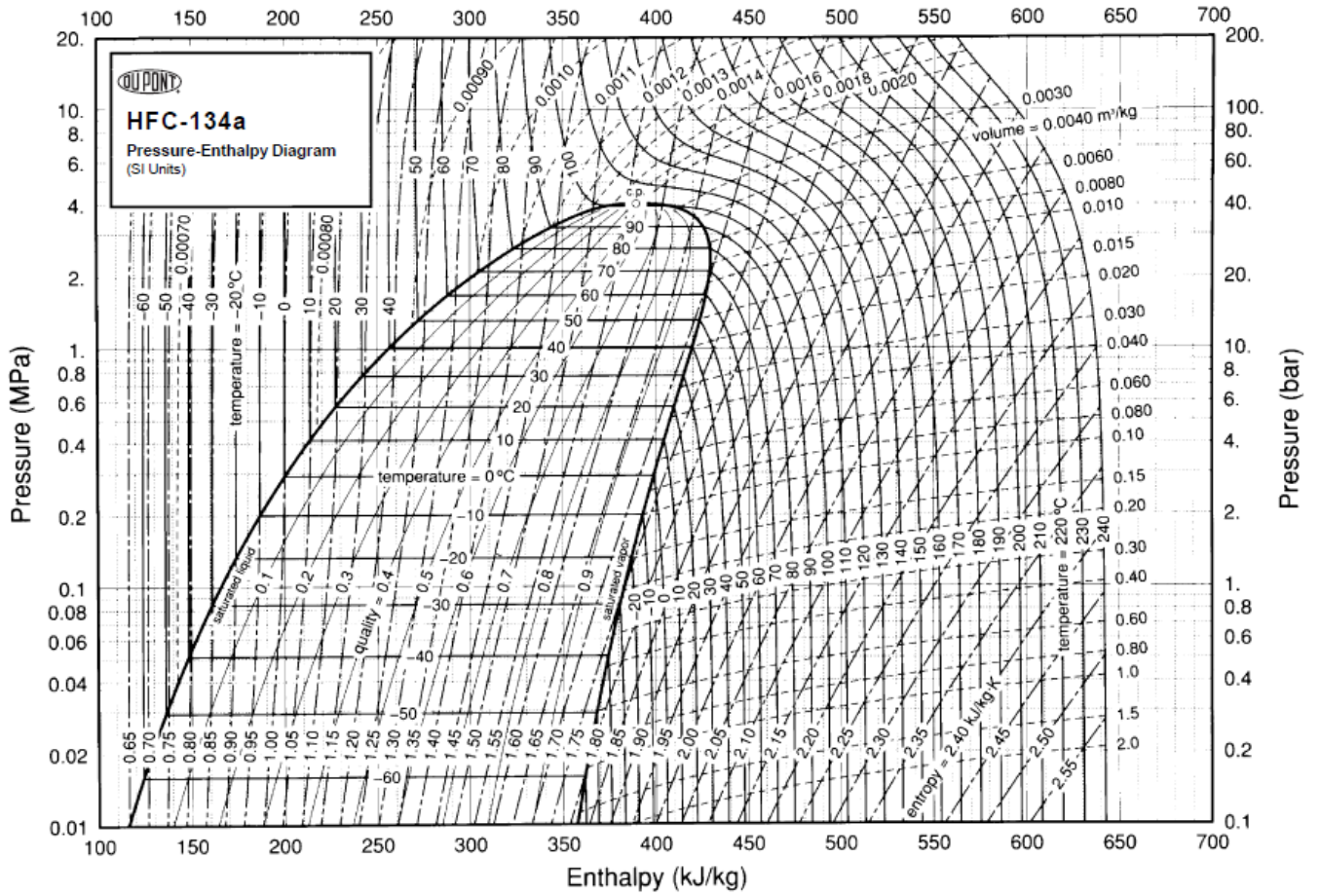
XVI. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=XO2PBDMEHfs&list=PLJjrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=8
- https://www.youtube.com/watch?v=urFrdSAJmyM&list=PLJjrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=9
- <https://www.youtube.com/watch?v=RR-3Uq--4Oo>

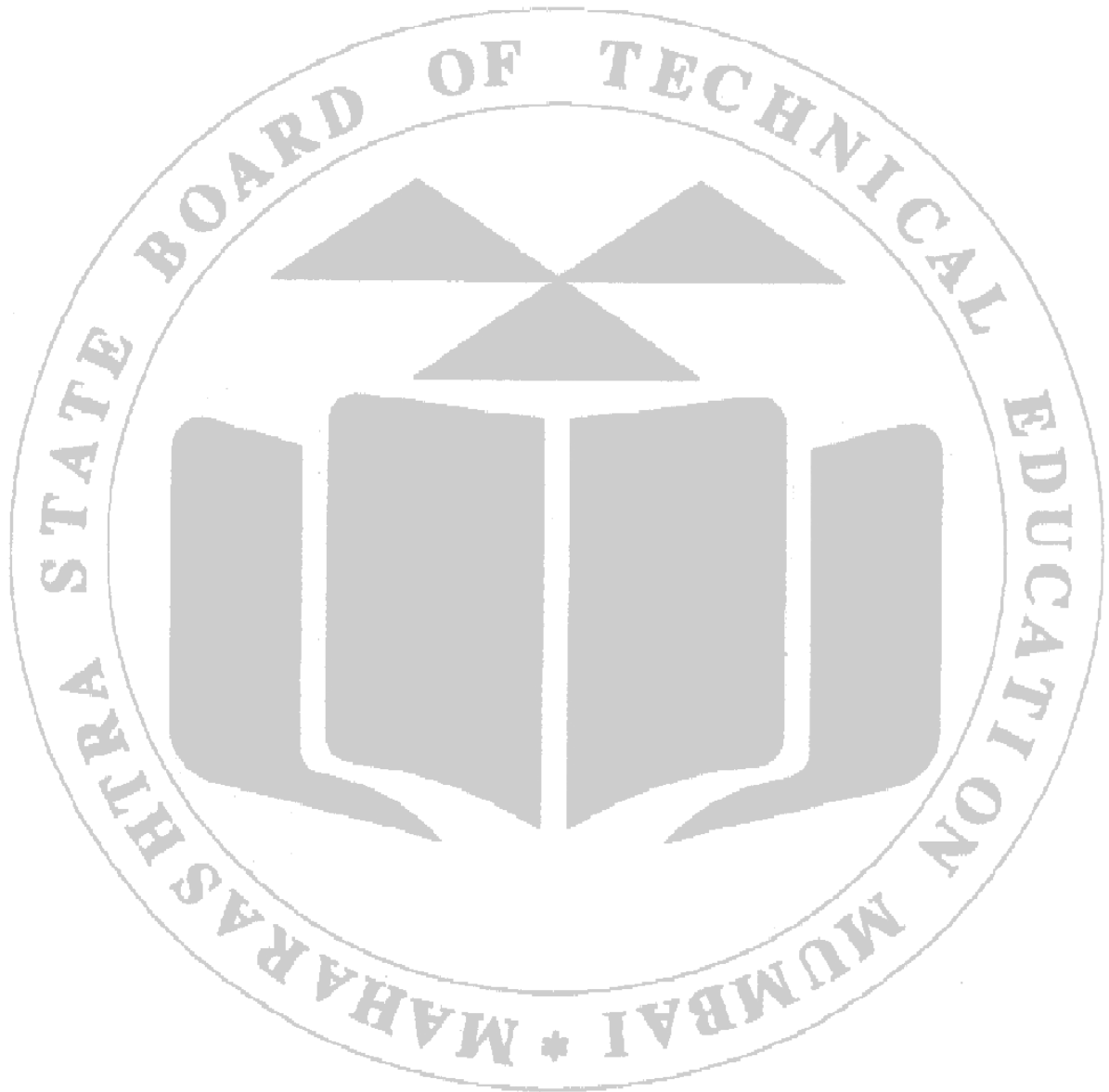
XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Ability to operate the refrigeration test rig	20%
2	Ability to measure pressure & temperature at salient points of the system	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	



[Space for P-H Chart]
(The student should paste the P-H chart of the respective Refrigerant)



Practical No. 3: Assemble / Dismantle various Components of water cooler

I. Practical Significance

The practical exercise of assembling and dismantling various components of a water cooler holds significant practical importance in technical and vocational training. It provides students with essential hands-on experience, allowing them to develop the skills required to handle tools and components effectively. Through this activity, students gain a clear understanding of the function and interconnection of each part, such as the compressor, condenser, fan, and thermostat, which deepens their knowledge of how a water cooler operates as a complete system. It also equips them with the ability to identify and troubleshoot faults, which is crucial for maintenance and repair work in real-world settings. Additionally, this practical emphasizes the importance of safety protocols when dealing with electrical appliances and refrigerants, thereby fostering responsible and safe working habits. By bridging theoretical knowledge with real applications, the exercise enhances diagnostic thinking and problem-solving abilities. Ultimately, it prepares students for employment in the appliance repair and HVAC industries, making them more job-ready and industry-relevant.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer - “The students are expected to demonstrate the ability to safely and efficiently assemble, dismantle, and troubleshoot water cooler components, meeting industry standards for appliance maintenance and repair”.

III. Course Level Learning Outcome (CO)

CO 1- Assess the performance of given refrigeration systems.

IV. Laboratory Learning Outcome(s)

- Select the proper tools for dismantling/assembling.
- Perform the dismantling /assembling of given water cooler by following proper sequence.

V. Relative Affective Domain Related Outcome(s)

- Follow safety practices.
- Practice good housekeeping.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background

To perform this practical effectively, students must possess a fundamental theoretical understanding of refrigeration and appliance systems. They should be familiar with the basic principles of the refrigeration cycle, including the processes of evaporation, compression, condensation, and expansion, and understand the role of refrigerants in heat transfer. A clear knowledge of the functions of key components such as the compressor, condenser, evaporator,

fan, thermostat, and filter/drier is essential for identifying and correctly handling each part during assembly or disassembly. Understanding the correct use of common tools such as screwdrivers, pliers, spanners, and multimeters is also necessary. Students should be aware of the correct sequence for disassembling and reassembling parts, ensuring that components are handled carefully and installed accurately. This theoretical background provides the necessary foundation for carrying out the practical task with competence, safety, and confidence.

VII. Experimental setup

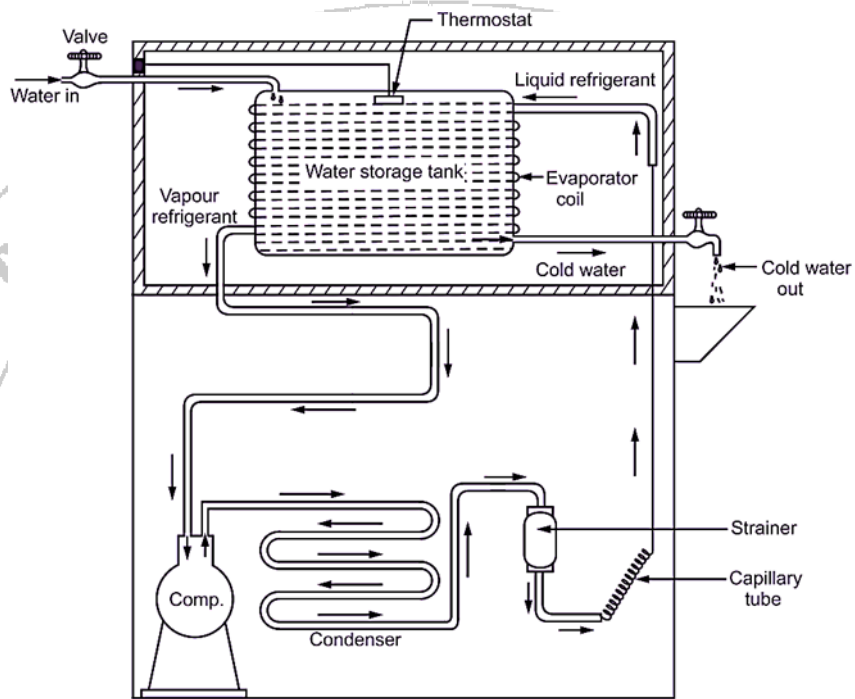


Figure 3.1 Schematic diagram of a Water cooler



Figure 3.2 Water cooler

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Actual working or scrap unit of water cooler	minimum 200-liter capacity, having all necessary parts	1
2	HVAC Tool Box	Flaring tool, Spanner, Piercing Pliers, Hammer, Side cutter, Cordless screw driver, Rounding tool	1

IX. Precautions to be Followed

- Avoid improper handling of the water cooler system.
- Use special and recommended tools for the assembly and dismantling of the water cooler.
- Use a clean workbench for assembly and dismantling.
- Unplug the water cooler before dismantling.

X. Procedure

1. Visually inspect the unit.
2. Power off the cooler and unplug it from the power source
3. Drain any remaining water from the cooler by opening the drain valve or removing the water tank.
4. Use a screwdriver to remove all screws that hold the outer body or casing of the cooler
5. Disconnect the water inlet pipe by loosening any screws or using pliers.
6. Locate the water pump inside the unit.
7. Carefully remove the fan and motor assembly from the unit.
8. Inspect electrical wiring and components.
9. Inspect all electrical components (motor, fan, and pump) for any visible wear or damage.
10. Cut all visible protruding parts and store them separately.
11. Unscrew the compressor manually with a spanner.
12. Position the water pump back into its original place.
13. Reconnect the electrical wiring to the water pump, ensuring it is secure and insulated.
14. Place the fan and motor assembly back into the unit.
15. Position the water tank back into the unit.
16. Reconnect the water inlet pipe to the tank.
17. Align the outer casing or panels back onto the unit.

XI. Observations and calculations

Component/Part	Tools Used	Technical Observations/Faults	Action needs to be taken
Water Cooler Unit			
Outer Body			
Water Tank			
Water Pump			
Compressor			
Condenser			
Cooling Fan & Motor			
Filter			
Evaporator coil			

XII. Results

XIII. Interpretation of Results

XVI. References / Suggestions for Further Reading

- <https://archive.nptel.ac.in/content/storage2/courses/112105129/pdf/RAC%20%20Lecture%201.pdf>
- <https://archive.nptel.ac.in/courses/112/105/112105129/>
- <https://www.youtube.com/watch?v=Yv9QuJTecI>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the toolkit tools	20%
2	Identification of water cooler components	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 4: Use of sling psychrometer

I. Practical Significance

The sling psychrometer is a simple instrument used to measure relative humidity by comparing dry bulb and wet bulb temperatures. Through this experiment, students develop a basic understanding of the psychrometric properties of air, such as humidity, which are important in various engineering fields, including mechanical, civil, environmental, and HVAC (Heating, Ventilation, and Air Conditioning). For mechanical engineers, understanding air properties like temperature, humidity, dew point, and enthalpy is crucial for designing and analyzing air conditioning systems, cooling towers, refrigeration units, and ventilation systems. For example, in HVAC systems, precise humidity measurements are vital for creating and maintaining comfortable indoor environments. Students also learn to operate basic meteorological tools, enhancing their observational skills and analytical thinking. Additionally, this practical session improves their abilities in instrument handling, manual data collection, and using psychrometric charts, which are commonly applied in mechanical engineering.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer -
“Ability to accurately measure and analyze humidity using a sling psychrometer for effective application in HVAC, thermal systems, and environmental control.”

III. Course Level Learning Outcome (CO)

CO2 - Measure the cooling capacity of air-conditioning systems.

IV. Laboratory Learning Outcome(s)

Measure air properties of conditioned air, such as dry bulb temperature, wet bulb temperature using a sling psychrometer.

V. Relative Affective Domain Related Outcome(s)

- Follow safety practices.
- Practice good housekeeping.
- Demonstrate working as a leader/team member.
- Maintain tools and equipment.
- Follow ethical practices.

VI. Minimum Theoretical Background

A sling psychrometer is a simple instrument used to measure relative humidity in the atmosphere. It consists of two thermometers: a dry bulb thermometer, which measures the ambient air temperature, and a wet bulb thermometer, which has a moist cloth (wick) wrapped around its bulb. When the psychrometer is rotated or "slung" through the air, evaporation from the wet bulb causes cooling, resulting in a lower temperature reading compared to the dry bulb. The rate of this cooling depends on the moisture content of the

air; drier air causes more evaporation and a greater temperature drop, while humid air causes less. The difference between the dry bulb and wet bulb temperatures is called the wet bulb depression, and it is directly related to the relative humidity. By using standard psychrometric tables or charts, students can determine the relative humidity of the air based on the observed temperature difference.

VII. Experimental setup



Figure 4.1 Digital Psychrometer



Figure 4.2 Sling Psychrometer

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Sling Psychrometer	Temperature Range -10°C to 50°C Accuracy - $\pm 0.5^\circ\text{C}$ Resolution - 0.5°C or 1.0°C Thermometer Type -Mercury or alcohol-filled glass thermometers	1

IX. Precautions to be Followed

- Avoid dropping or hitting the psychrometer against surfaces.
- Ensure the thermometers are intact and not leaking.
- The wet bulb wick should be thoroughly soaked with clean, distilled water before use.
- Conduct the test in an open, well-ventilated area to ensure proper airflow across the bulbs

X. Procedure

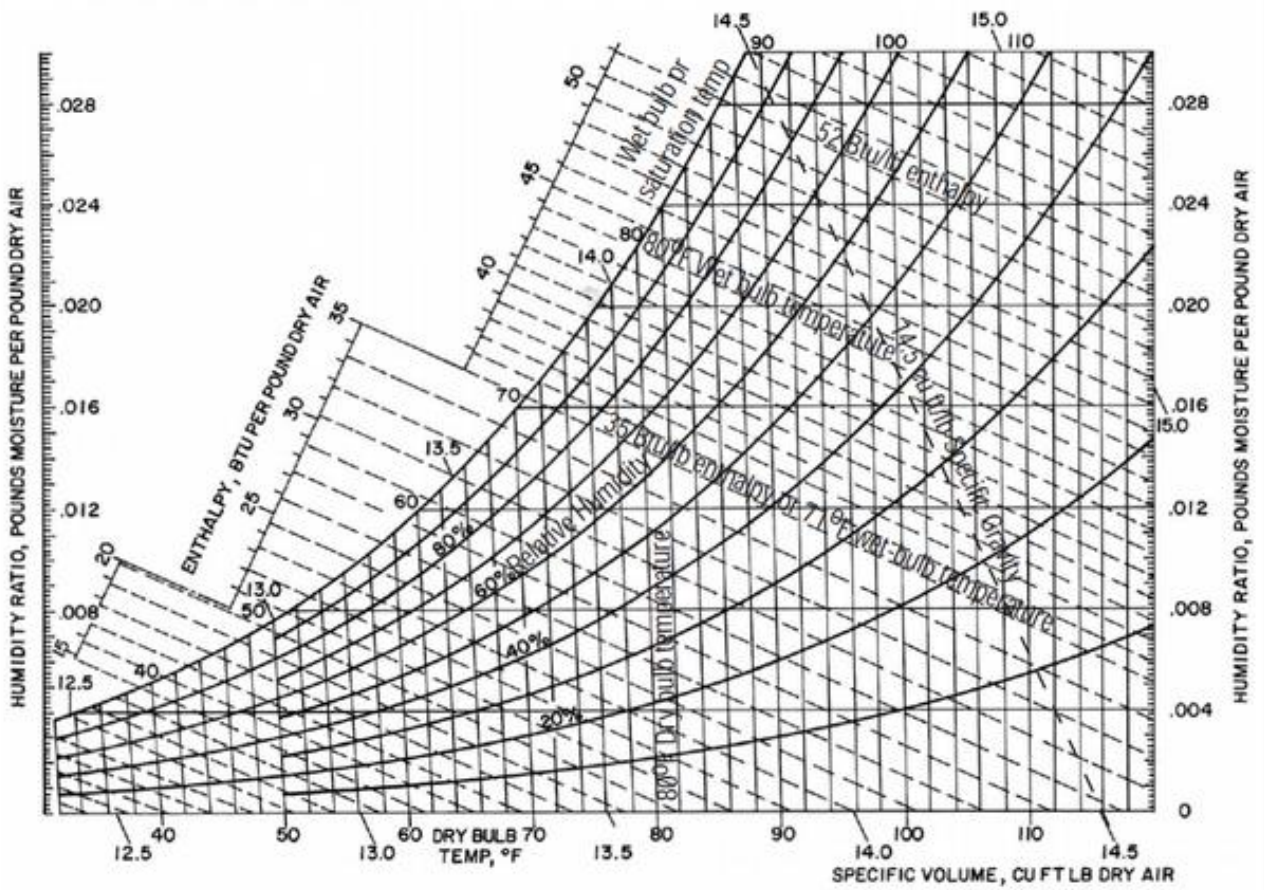
Note- For manually operated sling psychrometer)

1. Dip the cotton wick around the wet bulb in clean distilled water using a dropper or by submerging it in a small container.
2. Ensure the wick is fully saturated and covers the bulb tightly and evenly.
3. Record the initial dry bulb and wet bulb temperatures before spinning.
4. Hold the handle firmly and swing the sling psychrometer in the air for about 1–2 minutes at a consistent speed
5. Ensure good airflow and avoid areas with direct sunlight, heaters, or fans.
6. Stop swinging, and immediately record the Dry Bulb Temperature and Wet Bulb Temperature.
7. Repeat the process 2–3 times to ensure consistent and accurate readings.
8. Calculate the Wet Bulb Depression.
9. Use a psychrometric chart or humidity tables to find the relative humidity corresponding to the dry bulb temperature and wet bulb depression

XI. Observations and calculations

Location	Dry Bulb Temperature (DBT)	Wet Bulb Temperature (WBT)	Wet Bulb Depression ($^\circ\text{C}$)	Relative Humidity (%)	Specific Humidity Kg/Kg of dry air

Location	Dry Bulb Temperature (DBT)	Wet Bulb Temperature (WBT)	Wet Bulb Depression (°C)	Relative Humidity (%)	Specific Humidity Kg/Kg of dry air



Psychrometric Chart

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendations

XV. Practical Related Questions

1. State the working of a sling psychrometer.
2. Describe why the wet bulb temperature is usually lower than the dry bulb temperature during sling psychrometer operation
3. Define wet bulb depression and explain its significance in determining relative humidity
4. Evaluate the difference in results between a properly soaked and a dry wick in a sling psychrometer reading
5. Explain how sling psychrometer readings help assess environmental conditions for HVAC system design and operation.

[Space for Answer]

XVI. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=8Id1SZQpWY0&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=23
- https://www.youtube.com/watch?v=e2IryaMQQ6A&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=24
- https://www.youtube.com/watch?v=l_3K5Hr6bB8&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=25

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the measuring Instrument	20%
2	Observation and Recording Skills	20%
3	Calculation of final readings	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 5: Assemble / Dismantle various components of window air conditioner.

I. Practical Significance

This practical will provide hands-on experience with HVAC equipment, enabling students to closely examine and understand the internal layout and operation of various components, including the compressor, evaporator, condenser, fan motor, and thermostat. Practical skills development is essential for careers in HVAC servicing and appliance maintenance, including maintenance, fault diagnosis, and repair. Through this exercise, students also gain insight into how mechanical and electrical systems integrate and function together within an air conditioner. They learn to identify common faults, such as poor cooling, abnormal noises, or water leakage, and apply standard troubleshooting techniques, which builds their analytical and problem-solving abilities. Moreover, safety awareness is emphasized during the practical, including the correct use of tools, handling of electrical components, and basic knowledge of refrigerant safety.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer -
“The students are expected to demonstrate the ability to safely and efficiently assemble, dismantle, and troubleshoot water cooler components, meeting industry standards for appliance maintenance and repair”.

III. Course Level Learning Outcome (CO)

CO2 - Measure the cooling capacity of air-conditioning systems.

IV. Laboratory Learning Outcome(s)

- Select the proper tools for dismantling/assembling.
- Perform the dismantling /assembling of the given window air conditioner by following proper sequence

V. Relative Affective Domain Related Outcome(s)

- Follow safety practices.
- Practice good housekeeping.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background

To perform this practical effectively, students must possess a foundational understanding of several theoretical concepts related to air conditioning systems. They should have a clear knowledge of basic refrigeration principles, including the refrigeration cycle (evaporation, compression, condensation, and expansion) and how it is applied in air conditioning. A window air conditioner is a compact, self-contained unit that is typically installed in a window

or a wall opening, designed to cool a single room. It operates on the principle of the vapor compression refrigeration cycle, which includes four main stages: compression, condensation, expansion, and evaporation. Understanding this cycle is crucial, as it explains how heat is absorbed from the room and released outside, resulting in cooling. The main components involved in this cycle include the compressor, which compresses low-pressure refrigerant gas and turns it into a high-pressure, high-temperature gas. This gas then flows through the condenser coil, where it releases heat to the outside air and condenses into a liquid. The liquid refrigerant then passes through the expansion device, typically a capillary tube, which reduces its pressure and temperature. After expansion, the refrigerant enters the evaporator coil, where it absorbs heat from the room air and evaporates into a low-pressure gas again. This gas returns to the compressor, and the cycle repeats. Along with these core components, students must be familiar with auxiliary parts such as the blower or fan, which helps circulate room air over the evaporator and outdoor air over the condenser. The air filter traps dust and improves air quality, while the thermostat monitors and controls the room temperature by regulating the compressor's operation. A basic understanding of electrical components is also necessary, including the capacitor, overload protector, and wiring connections, which ensure the proper functioning of the compressor and fan motor.

VII. Experimental setup

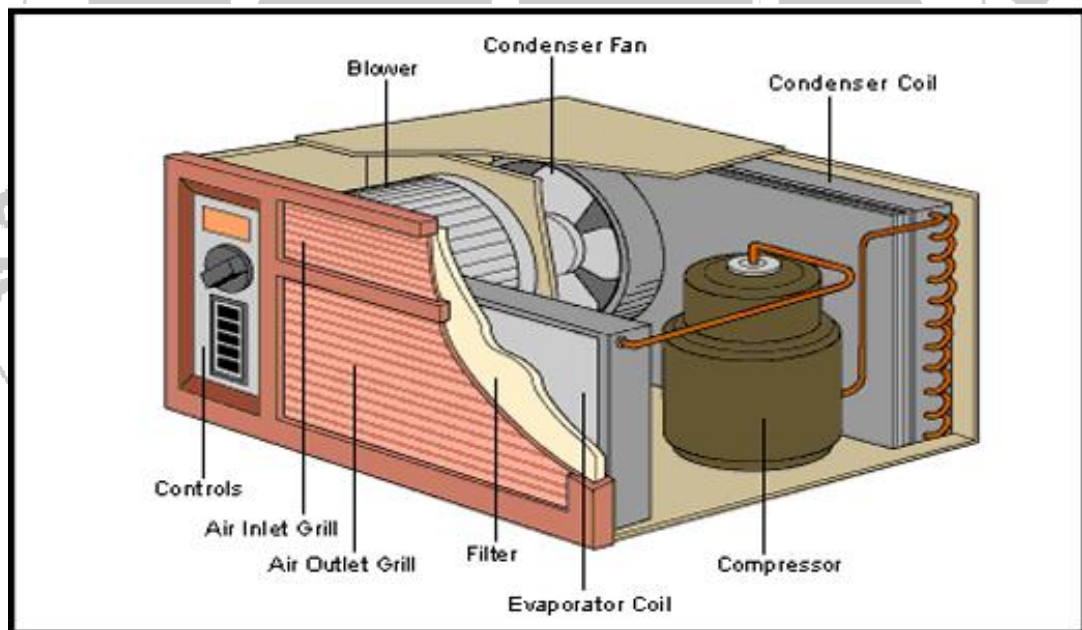


Figure 5.1 Window air conditioner unit

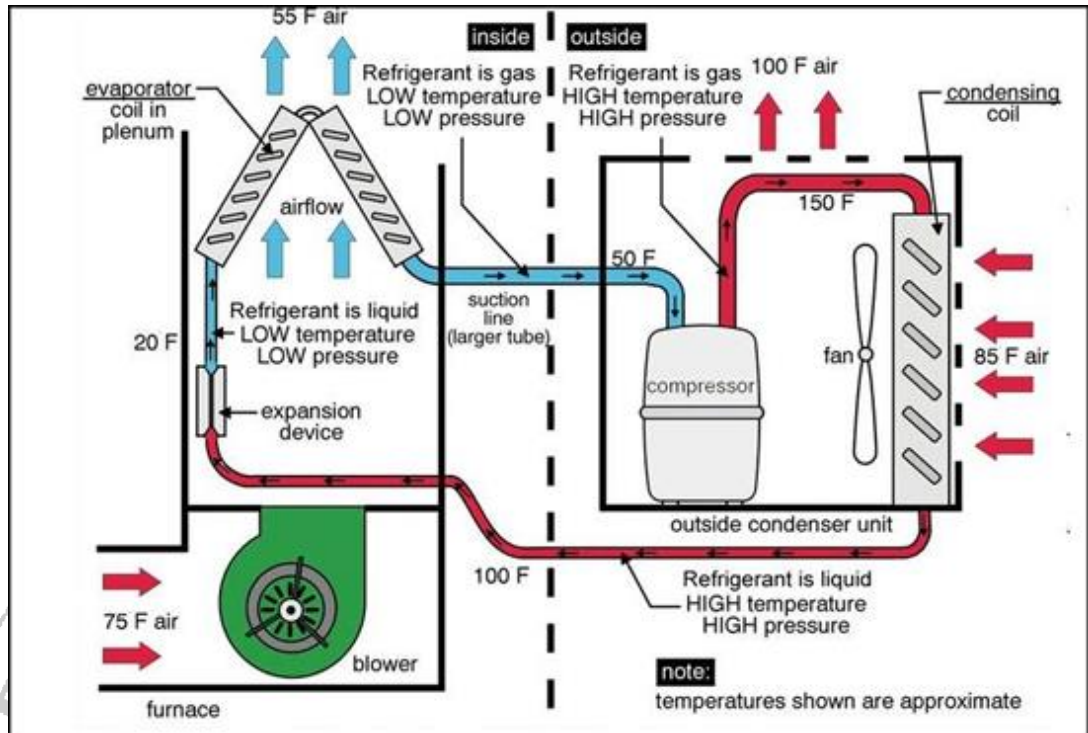


Figure 5.2 Schematic diagram of Window air conditioner

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Actual working or scrap unit of a window air conditioner	As per standard having all necessary parts	1
2	HVAC Tool Box	Flaring tool, Spanner, Piercing Pliers, Hammer, Side cutter, Cordless screw driver, Rounding tool	1

IX. Precautions to be Followed

- Avoid improper handling of the system.
- Use special and recommended tools for the assembly and dismantling of window air conditioner unit.
- Use a clean workbench for assembly and dismantling.
- Unplug the window air conditioner unit before dismantling.

X. Procedure

1. Visually inspect the unit
2. Power off the window air conditioner unit and unplug it from the power source
3. Remove Front Grille and Filter.
4. Unscrew the control panel cover (contains switches, thermostat, and wires).

5. Unscrew and lift off the metal outer shell (cabinet).
6. Unscrew and pull off the evaporator (indoor) and condenser (outdoor) fan blades from the motor shaft.
7. Remove the Blower and Fan Motor.
8. Identify the compressor, copper tubing, and capacitor.
9. Reinstall the Fan Motor and Blades.
10. Reattach the Control Panel.
11. Place the Outer Case.
12. Insert Filter and Front Grille.
13. Inspect all components.

XI. Observations and calculations

Component/Part	Tools Used	Technical Observations (Observed condition)	Action needs to be taken
Front Grille / Cover			
Air Filter			
Control Panel (Switches, Thermostat)			
Outer Body (Metal Body)			
Evaporator Coil (Indoor)			
Condenser Coil (Outdoor)			
Blower Fan (Indoor)			
Condenser Fan (Outdoor)			
Fan Motor			
Compressor			

XII. Results

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XIII. Interpretation of Results

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XIV. Conclusions and Recommendations

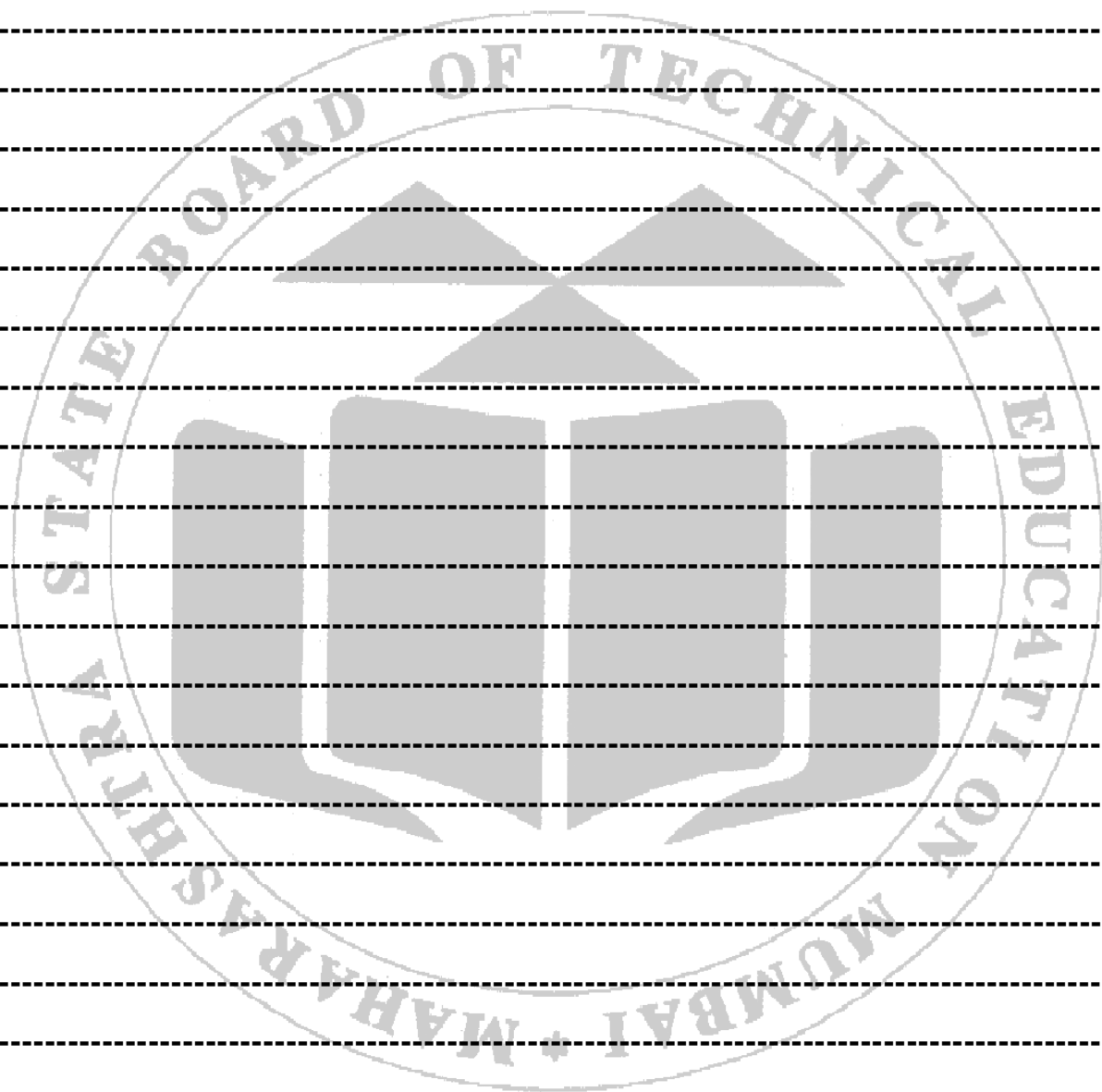
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XV. Practical Related Questions

1. Describe the primary function of a window air conditioner in maintaining indoor thermal comfort
2. Explain the location and role of the evaporator coil in the cooling process of a window air conditioner.
3. List the safety precautions necessary before servicing or dismantling a window air conditioner.
4. Explain the common problems that occur with air filters in window AC units and their effects on performance.
5. List the names of Indian manufacturers of window air conditioners along with their range of capacity in TR.

[Space for Answer]

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XVI. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=ExNJoT_2XeI&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=22.
- https://www.youtube.com/watch?v=v_kptwIoaM8&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=18
- https://www.youtube.com/watch?v=1DguNZsvZc0&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=38
- <https://www.youtube.com/watch?v=kfnJPj2o8XM>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the toolkit tools	20%
2	Identification of components	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 6: Test on window air conditioner

I. Practical Significance

This practical exercise is particularly significant for students as it provides them with a comprehensive understanding of HVAC systems, which are integral to modern infrastructure. A window air conditioner comprises essential HVAC components, including the compressor, condenser, evaporator, expansion valve, and fan. By engaging in testing these units, students gain firsthand experience in identifying and understanding the function of each component, measuring and interpreting parameters like temperature, pressure, and airflow, and assessing system performance under various operating conditions. This exposure is crucial, as HVAC systems are integral to modern infrastructure, and proficiency in their operation and maintenance is highly valued in the industry.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer –

- Ability to analyze and interpret air conditioning system performance.
- Capability to handle instrumentation and troubleshoot air conditioning systems.
- Application of thermodynamics and heat transfer in practical setups.

III. Course Level Learning Outcome (CO)

CO2 - Measure the cooling capacity of air-conditioning systems.

IV. Laboratory Learning Outcome(s)

- Perform a test using a window air conditioner to measure temperature, pressure, mass flow rate, etc.
- Perform a test using a window air conditioner to determine its COP.

V. Relative Affective Domain Related Outcome(s)

- Follow safety practices.
- Practice good housekeeping.
- Work as a leader / a team member.
- Follow ethical Practices.
- Promote teamwork and communication during group experiments.

VI. Minimum Theoretical Background

A window air conditioner (AC) is a compact, self-contained unit designed for cooling individual rooms. It operates on the principles of the vapor-compression refrigeration cycle, utilizing refrigerant to transfer heat from the indoor air to the outdoor environment. The primary components of a window AC include the compressor, condenser, expansion valve (or capillary tube), evaporator, and fans. The compressor, located on the outdoor side of the unit, compresses the refrigerant gas, raising its pressure and temperature. This high-pressure, high-temperature gas then flows into the condenser coils, where it releases heat to the surrounding

air and condenses into a high-pressure liquid. The liquid refrigerant passes through the expansion valve, experiencing a pressure drop that cools it significantly. This low-pressure, cold liquid refrigerant then enters the evaporator coils inside the room. As the indoor air blows over the evaporator coils, the refrigerant absorbs heat from the air, causing it to evaporate into a gas. The cooled air is then circulated back into the room, lowering the indoor temperature. The efficiency of a window AC is often measured using the Coefficient of Performance (COP), defined as the ratio of heat removed from the cooled space to the work input required.

VII. Experimental setup



Figure 7.1: Window air conditioner test rig

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Window air conditioner test rig with 1 to 2 TR cooling capacity	Compressor: Hermitically sealed compressor with a capacity of 1 Ton. Condenser: Air-cooled. Condenser cooling fan Pressure Gauges: 2 Nos. (For suction & discharge pressure) Evaporator: Window type Expansion Device: Capillary Tube compatible capacity. Temperature Sensor: RTD PT-100 Type. Digital Voltmeter: 0-500 V Digital Ammeter: 0-20 Amp. Digital Temperature Indicator with multi-channel switch.	1

IX. Precautions to be Followed

- Ensure there is no leakage of refrigerant before starting the experiment.
- Never operate the unit, keeping the condenser fan switched off.
- Before taking any readings, allow the system to run for at least 5–10 minutes so that it reaches a steady-state operating condition.
- Run the system under recommended conditions only — avoid exceeding specified pressure and temperature limits.
- Start and shut down the compressor gradually.
- Do not block airflow to the condenser or evaporator coils
- Do not touch electrical connections or the wattmeter with wet hands.

X. Procedure

1. Record the ambient dry bulb temperature (DBT) and wet bulb temperature (WBT) using the sling psychrometer.
2. Switch on the AC unit and set it to the desired cooling mode.
3. Allow the system to reach steady-state operation, typically after 15–20 minutes.
4. Measure and record Evaporator inlet and outlet temperature, Condenser inlet and outlet temperature, and temperature of air entering and leaving the conditioned space at regular intervals.
5. Measure the condenser and evaporator side refrigerant pressures.
6. Measure the Electrical Power Consumption from the energy meter.

XI. Observations and calculations

Observations:

Sr. No.	Description	Symbol	Unit	Reading Value
1	Ambient Dry Bulb Temperature	DBT ₁	°C	
2	Ambient Wet Bulb Temperature	WBT ₁	°C	
3	Chilled Air-Dry Bulb Temperature	DBT ₂	°C	
4	Chilled Air Wet Bulb Temperature	WBT ₂	°C	
5	Evaporator pressure	P _e	bar	
6	Condenser pressure	P _c	bar	
7	Evaporator Inlet Temperature	t _{ei}	°C	
8	Evaporator Outlet Temperature	t _{eo}	°C	
9	Condenser Inlet Temperature	t _{ci}	°C	
10	Condenser Outlet Temperature	t _{co}	°C	
11	Time for 10 revolutions of pulses of the energy meter.	T _c	sec	
12	Energy meter constant for Compressor	N _c	(rev/kWh)	

Calculations:

Actual COP

1. Mass Flow Rate of Air (ṁ):

$$\dot{m} = 0.717 \times \sqrt{\Delta H}$$

$$= \dots\dots\dots$$

$$= \dots\dots\dots \text{ Kg/sec.}$$

Where: ΔH = Difference in water manometer level (m).

2. Refrigeration Effect (Q):

$$Q = \dot{m} \times C_p \times \Delta T$$

$$= \dots\dots\dots$$

$$= \dots\dots\dots \text{ KJ/sec}$$

Where, C_p = Specific heat of air (approximately 1.006 kJ/kg·°C).

ΔT = Temperature difference between inlet and outlet air in °C

3. Work Done by Compressor (W):

$$W = \frac{3600 \times 10}{N \times t}$$

$$= \dots\dots\dots$$

W = KJ/sec

Where N = Energy meter constant (rev/kWh).

t = Time for 10 revolutions (sec).

Actual COP = Q/W

$$= \dots\dots\dots$$

$$= \dots\dots\dots$$

Theoretical COP

Plot the cycles on P-h chart for the refrigerant used and fill in the table given below for Calculation of theoretical COP

Sr. No.	Description	Symbol	Reading in kJ/kg
1	Enthalpy at evaporator inlet	h _{ei}	
2	Enthalpy at evaporator outlet	h _{eo}	
3	Enthalpy at condenser inlet	h _{ci}	
4	Enthalpy at condenser outlet	h _{co}	

$$\text{Theoretical COP} = \frac{\text{(Theoretical Refrigerating Effect)}}{\text{(Theoretical Compressor Work)}}$$

$$= \frac{(h_{eo} - h_{ei})}{(h_{ci} - h_{eo})}$$

$$= \frac{(\dots\dots\dots - \dots\dots\dots)}{(\dots\dots\dots - \dots\dots\dots)}$$

$$= \dots\dots\dots$$

XII. Results

Theoretical COP =

Actual COP =

XIII. Interpretation of Results

XIV. Conclusions and Recommendations

XV. Practical Related Questions

1. List the main components of a window air conditioner and their functions.
2. Measure the inlet and outlet air temperatures and airflow rate, and calculate the cooling capacity of a window AC unit using the heat transfer formula.
3. Use pressure-temperature readings and refrigerant charts to calculate superheat and subcooling values in a working window air conditioner
4. Discuss possible causes of water leakage in a window air conditioner, such as a clogged drain pipe, improper installation, or frozen coils
5. Describe the environmental effects of commonly used refrigerants (like R-22, R-32, R-410A) in terms of ozone depletion potential (ODP) and global warming potential (GWP).

[Space for Answer]

Practical No. 7: Demonstration of split air conditioner

I. Practical Significance

This practical will bridge the gap between theoretical learning and real-world application, allowing students to directly observe how the various components of a split air conditioning system work together. The demonstration enables students to become familiar with the individual components of a split air conditioning unit. They can identify and understand the function of both the indoor and outdoor units, observe the refrigerant lines and electrical connections, and learn about control systems and sensors. In addition to component identification, the demonstration provides insight into troubleshooting and diagnostic skills. By showing common operational issues such as refrigerant leaks, compressor failures, or thermostat malfunction, students can learn how to diagnose faults and apply logical methods to resolve them.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer -

- Understanding of split AC operation and refrigeration cycle.
- Basic troubleshooting and fault diagnosis capability.
- Proficiency in using HVAC tools and instruments.

III. Course Level Learning Outcome (s)

CO2 - Measure the cooling capacity of air-conditioning systems.

IV. Laboratory Learning Outcome(s)

- Measure the input current, voltage, working pressure, and temperature by using appropriate measuring instruments.
- Diagnose the faults in the given air-conditioning system.

V. Relative Affective Domain-related Outcome(s)

- Maintain tools and equipment.
- Follow ethical Practices.

VI. Relevant Theoretical Background

A split air conditioner is a type of cooling system that separates its main components into two units: an indoor unit and an outdoor unit, connected by refrigerant piping and electrical wiring. Understanding its operation requires knowledge of thermodynamics, refrigeration cycles, component functions, and control systems. Key components of a split AC system include the compressor, condenser coil, evaporator coil, expansion device, fan motors, filters, and refrigerant piping. The compressor, located in the outdoor unit, compresses low-pressure refrigerant gas into a high-pressure, high-temperature gas. This gas flows through the condenser coil, where it releases heat to the outside air and condenses into a high-pressure liquid. The liquid refrigerant then passes through an expansion valve (or capillary tube), which reduces its pressure and temperature. Finally, it enters the evaporator coil inside the indoor

unit, where it absorbs heat from the room air and evaporates back into a gas, thus cooling the indoor space. The refrigerant is a special fluid (such as R-22, R-410A, or R-32) that repeatedly changes state (from gas to liquid and back) during the refrigeration cycle.

VII. Experimental setup

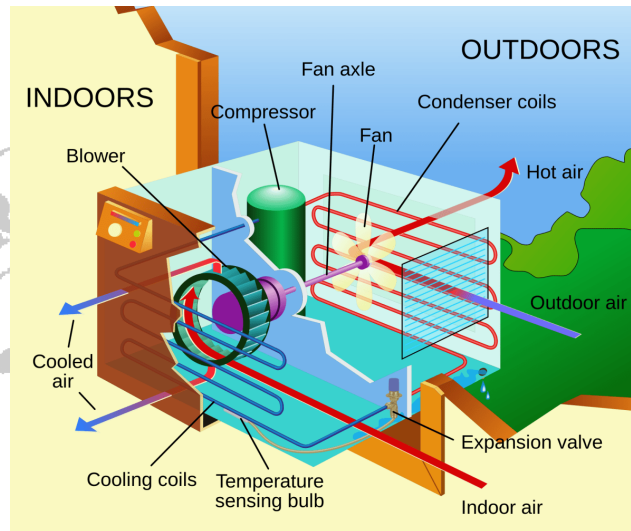


Figure 7.1 Schematic diagram of a Split air conditioner

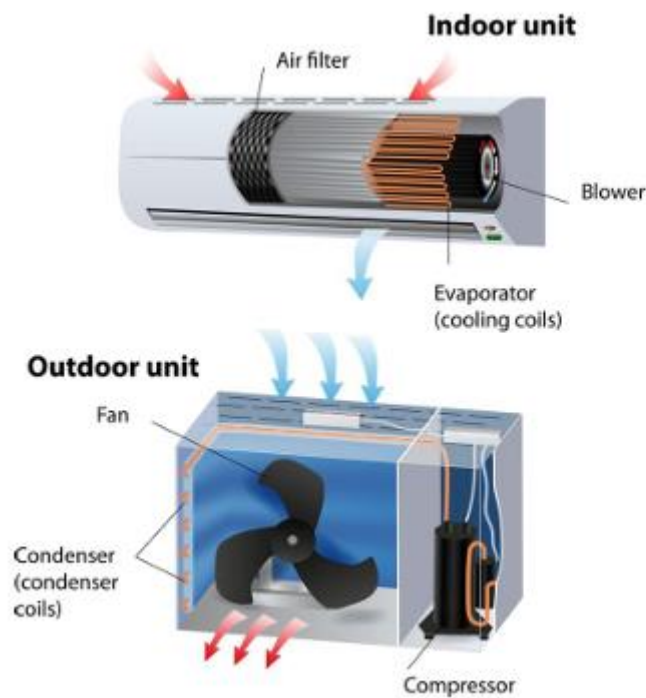


Figure 7.2 Schematic diagram of a Split air conditioner

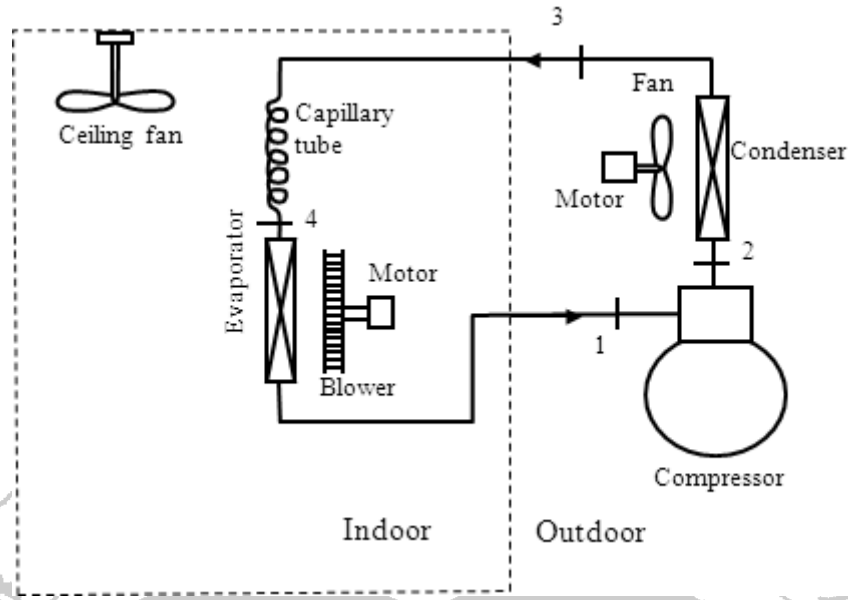


Figure 7.3 Circuit diagram of a split air conditioner

VIII. Required Resources/apparatus/equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Actual working unit of Split air conditioner	Capacity – 1 to 2 TR, as per standards	1
2	Digital Multimeter or Clamp Meter	As per standards	1
3	Voltmeter	0–300V A.C.	1
4	Ammeter	0–20A A.C.	1
5	Thermocouples or Temperature Sensors	RTD PT 100	1

IX. Precautions to be followed

- Avoid improper handling of all instruments.
- Avoid improper handling of the split air conditioner unit
- Use safety shoes.
- Switch off the main power supply before connecting any instruments.
- Avoid short-circuiting terminals while measuring.

X. Procedure

1. Set the voltmeter (or multimeter) to AC voltage mode.
2. Connect the voltmeter across the input terminals of the indoor or outdoor unit.
3. Switch on the power supply and note the voltage.
4. Use a clamp meter around the live wire supplying the air conditioner.
5. Set the clamp meter to the AC mode.
6. Turn on the air conditioner and allow it to stabilize (3–5 minutes).

7. Record the operating current.
8. Observe and record the low-side pressure and high-side pressure
9. Measure the Inlet air temperature and Outlet air temperature.

XI. Observation and calculations

Sr. No	Parameter	Measured Value	Standard Range	Remarks/Fault Diagnosis
1	Input Voltage (V)			
2	Input Current (A)			
3	Suction Pressure (Low Side)			
4	Discharge Pressure (High Side)			
5	Inlet Air Temperature (°C)			
6	Outlet Air Temperature (°C)			
7	Temperature Difference (ΔT °C)			

XII. Result(s)

XIII. Interpretation of results

XVI. References/Suggestions for further reading

- https://www.youtube.com/watch?v=YUgN5Dbmpg&list=PLJjrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=36
- https://www.youtube.com/watch?v=XO2PBDMEHfs&list=PLJjrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=8
- https://www.youtube.com/watch?v=474sNpYYWSY&list=PLJjrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=10
- https://www.youtube.com/watch?v=e2IryaMQQ6A&list=PLJjrv2_3aFXdh1PQVeO1RR1_NmXiiPZh0&index=24

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the measuring Instruments	20%
2	Taking readings of required parameters	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 8: Test on air conditioning test rig.

I. Practical Significance

The primary objective of engaging with an air conditioning test rig is to familiarize students with the vapor compression cycle, the fundamental operating principle of most air conditioning systems. By performing experiments on the test rig, students can observe and analyze the various stages of the cycle, including compression, condensation, expansion, and evaporation. This practical exposure enables students to comprehend the thermodynamic processes involved and the factors influencing system performance. Furthermore, practical tests on the air conditioning rig facilitate the calculation of key performance indicators such as the Coefficient of Performance (COP). By measuring parameters like temperature, pressure, and power consumption, students can determine the efficiency of the system and identify areas for optimization.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer –

- Ability to analyze and interpret air conditioning system performance.
- Capability to handle instrumentation and troubleshoot air conditioning systems.
- Application of thermodynamics and heat transfer in practical setups.

III. Course Level Learning Outcome (CO)

CO2 - Measure the cooling capacity of air-conditioning systems.

IV. Laboratory Learning Outcome(s)

- Perform the test using air conditioning test rig to measure the various parameters like temperature, pressure, mass flow rate of air, etc.
- Calculate the COP and cooling capacity of the given air conditioning system.

V. Relative Affective Domain-related Outcome(s)-

- Follow safety practices.
- Practice good housekeeping.
- Work as a leader / a team member.
- Follow ethical Practices.
- Promote teamwork and communication during group experiments.

VI. Minimum Theoretical Background

Air conditioning systems are engineered to control the temperature, humidity, and air quality of indoor environments, ensuring comfort and preserving the integrity of sensitive equipment or materials. The fundamental principle behind most air conditioning systems is the vapor compression refrigeration cycle, which involves the phase change of a refrigerant to absorb and release heat. The vapor compression cycle operates through four main stages: Compression: The refrigerant gas is compressed in the compressor, raising its pressure and

temperature. Condensation: The high-pressure, high-temperature gas then passes through the condenser, where it releases heat to the surroundings and condenses into a high-pressure liquid. Expansion: This high-pressure liquid refrigerant then flows through an expansion valve, where its pressure drops, causing it to cool and partially evaporate. Evaporation: The cold refrigerant absorbs heat from the indoor air in the evaporator coil, causing it to evaporate completely and return to the compressor to repeat the cycle. The efficiency of an air conditioning system is often measured by its Coefficient of Performance (COP), which is the ratio of useful cooling provided to the work input required. An air conditioning test rig is a laboratory setup designed to simulate the operation of an air conditioning system under controlled conditions.

VII. Experimental setup

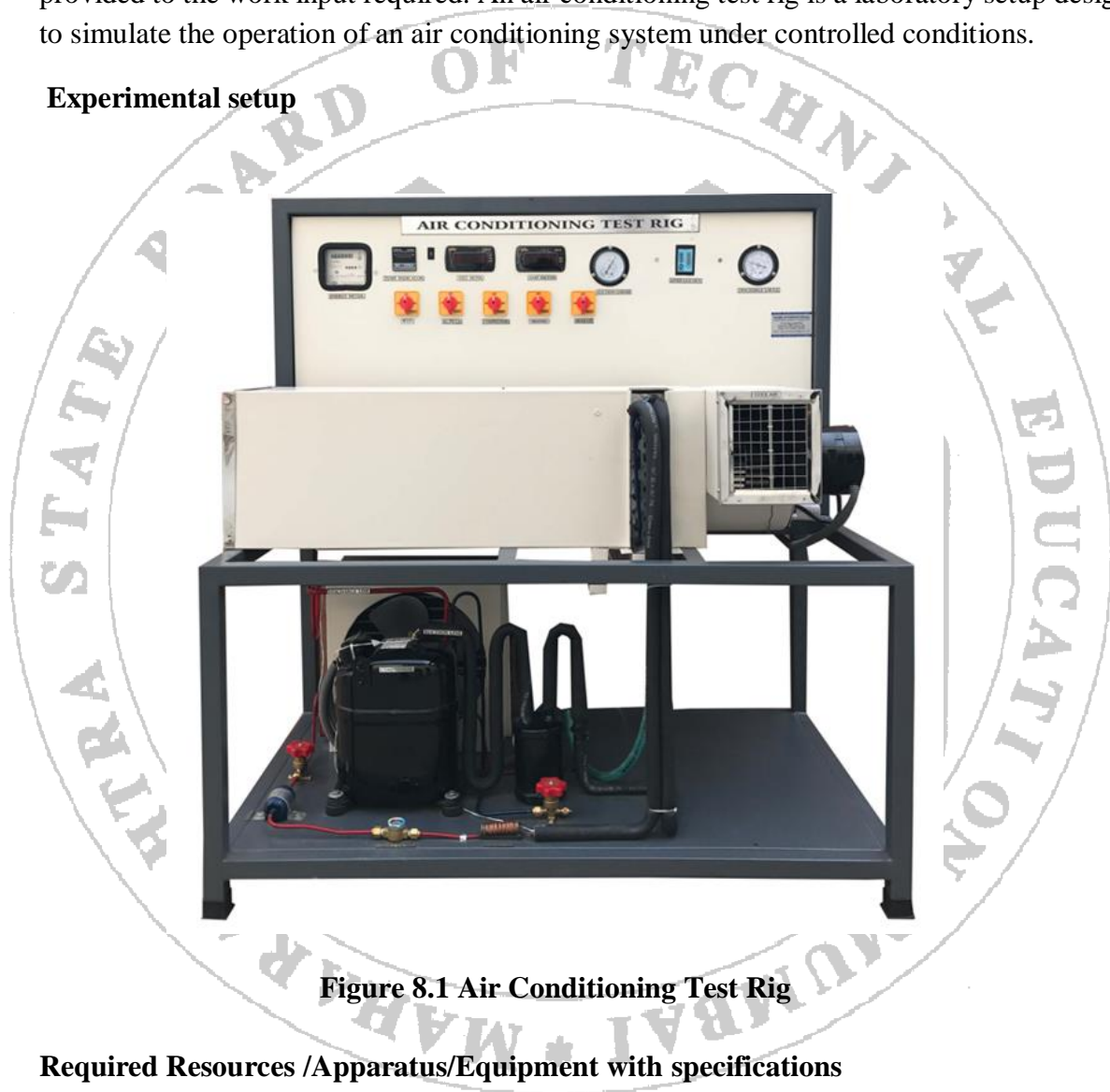


Figure 8.1 Air Conditioning Test Rig

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Actual Working Model of Air Conditioning Test Rig	Capacity – 1 to 2 TR, as per standards Compressor: Hermitically sealed compressor, reciprocating type. Capacity 1 Ton	1

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
		Condenser: Air cooled compatible to 1 Ton compressor Condenser cooling fan: Compatible capacity with permanent lubricated motor. Pressure Gauges: 2 Nos Evaporator: Compatible with 1 Ton Expansion Device: Capillary Tube or TEV compatible capacity Temperature Sensor: RTD PT-100 Type Blower unit with 1HP, 3-phase motor.	

IX. Precautions to be Followed

- Ensure the system is adequately charged with the appropriate refrigerant, such as R134a or R22.
- Regularly check pressure and temperature readings to avoid exceeding system limits.
- Keep all ignition sources away from the test rig.
- Use safety shoes.

X. Procedure

1. Switch on the power supply of the unit and start the duct fan.
2. Start the condenser fan, and after a few minutes, start the compressor.
3. Allow the system to reach a steady operating condition.
4. Measure the dry bulb temperature of the air entering the evaporator/duct (ambient air) and leaving the evaporator/duct (chilled air).
5. Measure the air velocity with the pitot tube using the water U-tube manometer connected to the pitot tube in the air conditioning duct.
6. Measure the pressure and temperature of refrigerant at all required points, i.e., Evaporator inlet & outlet, Condenser inlet & outlet.
7. Note the time taken for 10 revolutions of the energy meter disc to calculate the input energy.

XI. Observations and calculations

Observation Table

Sr. No	Parameter	Value
1	Air Inlet Temperature (Atmospheric Conditions)	DBT =-----°C, WBT =-----°C
2	Air Outlet Temperature (Chilled Conditions)	DBT = -----°C, WBT =-----°C
3	Condenser inlet temperature	-----°C

Sr. No	Parameter	Value
4	Condenser outlet temperature	-----°C
5	Evaporator inlet temperature	-----°C
6	Evaporator outlet temperature	-----°C
7	Condenser Pressure (P _c)	-----Kg/cm ²
8	Evaporator Pressure (P _e)	-----Kg/cm ²
9	Air Velocity (V)	----- m/s
10	Pitot tube water manometer level difference (Δh)	-----meter
11	Time taken for 10 revolutions of compressor energy meter disc (T _c)	-----second
12	Compressor energy meter constant (N _c)	-----rev/kWhr

DBT = Dry Bulb Temperature, WBT = Wet Bulb Temperature

Calculations –

1. Theoretical COP

Plot the cycles on P-h chart for the refrigerant used and fill in the table given below for

Sr. No.	Description	Symbol	Reading in kJ/kg
1	Enthalpy at evaporator inlet	H _{ei}	
2	Enthalpy at evaporator outlet	H _{eo}	
3	Enthalpy at condenser inlet	H _{ci}	
4	Enthalpy at condenser outlet	H _{co}	

Theoretical COP

$$= (\text{Theoretical Refrigerating Effect}) / (\text{Theoretical Compressor Work})$$

$$= (h_{eo} - h_{ei}) / (h_{ci} - h_{eo})$$

$$= (\dots\dots\dots - \dots\dots\dots) / (\dots\dots\dots - \dots\dots\dots)$$

$$= \dots\dots\dots$$

2. Actual COP

Actual COP = (Actual Cooling Effect) / (Actual work supplied to compressor)

Actual Cooling Effect

Actual Cooling Effect = Total heat removed from air conditioner

$$= m_{air} \times (h_{atm} - h_{chilled})$$

m_{air} = Mass flow of air flowing through duct

Mass flow of air flowing through duct,

$$\dot{m}_{air} = \rho_a \times A \times \sqrt{\left(\frac{2 \times g \times \Delta h \times (\rho_m - \rho_a)}{\rho_a} \right)}$$

$$= \dots \dots \dots \text{kg/sec}$$

Where, g = acceleration due to gravity = 9.81 m/sec²

Δh = Manometric height in meters

ρ_m = Density of manometric fluid in kg/m³

ρ_a = density of air in kg/m³

A = Area of the duct in m²

From the psychrometric chart,

h_{atm} = Total enthalpy of air at atmospheric conditions = kJ/kg

$h_{chilled}$ = Total enthalpy of air at chilled conditions = kJ/kg

Actual Cooling Effect = Total heat removed from air conditioner

$$= m_{air} \times (h_{atm} - h_{chilled})$$

$$= \dots \dots \dots \text{kW}$$

Actual work supplied to the compressor (W_c)

$$W_c = (10 / N_c) \times (3600 / T_c) \text{ kW}$$

$$= (10 / \dots) \times (3600 / \dots) \text{ kW}$$

$$W_c = \dots \dots \dots \text{ kW}$$

Actual COP = (Actual Cooling Effect) / (Actual work supplied to compressor)

= -----

= -----

= -----

XII. Results

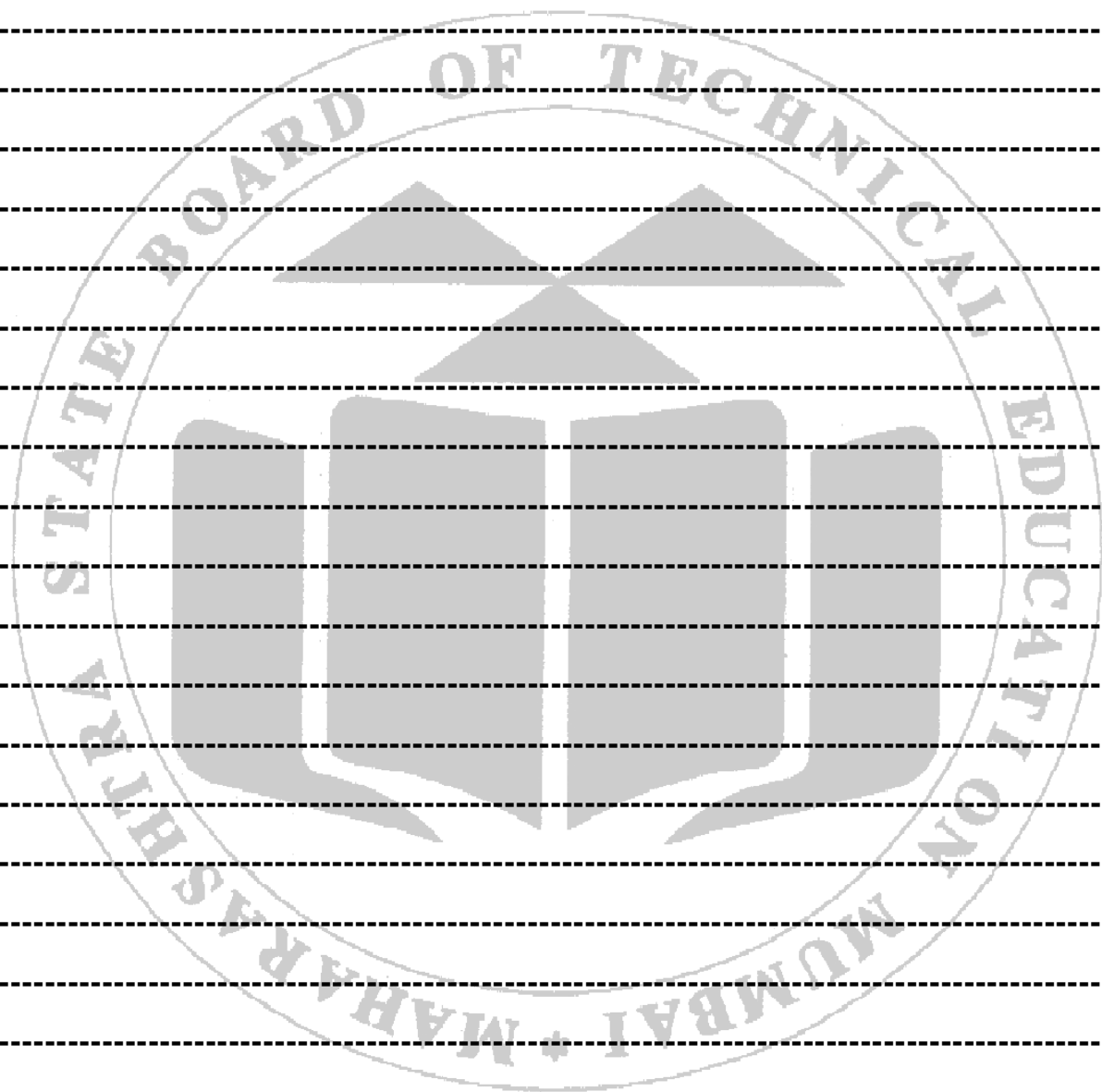
XIII. Interpretation of Results

XIV. Conclusions and Recommendations

XV. Practical Related Questions

1. Calculate the COP of an air conditioner using the given input power and cooling output data, and interpret what the result indicates about system efficiency
2. Calculate the cooling capacity of an air conditioner in BTU/hr or TR (ton of refrigeration) using airflow rate and temperature difference readings
3. State the factors affecting human comfort in an air-conditioned space
4. Name the main components of a basic air conditioning system.
5. Name any two psychrometric processes occurring in an air conditioning system.

[Space for Answer]



XVI. References / Suggestions for Further Reading

- https://www.youtube.com/watch?v=ExNJoT_2XeI&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=22
- https://www.youtube.com/watch?v=e2IryaMQQ6A&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=24
- https://www.youtube.com/watch?v=gRcgUfeAHl4&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=33
- https://www.youtube.com/watch?v=7Kd3pxDT2U&list=PLJjrv2_3aFXdh1PQVeO1RRI_NmXiiPZh0&index=34

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Ability to operate air conditioning test rig	20%
2	Ability to measure pressure & temperature at salient points of the system	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 9: Demonstration of I.C. Engine Test Rig

I. Practical Significance

Internal combustion engine (I.C. Engine) is a major prime mover for most types of vehicles, electric generators, agricultural equipment, and many other machineries due to its single, compact unit, convenience in use and maintenance, availability in a variety of modules, and reasonable cost. Still, the I.C. Engines are the backbone of the transport of Passengers and goods in our country. Its efficient performance in producing the required power with expected torque and speed, with minimum fuel consumption, emissions, and noise, is very significant for its user. So, it's testing at the manufacturer, approval authority; the user end becomes essential for the assurance of its performance. The outcome of the testing is brake power, indicated power, mechanical efficiency, thermal efficiency, specific fuel consumption, heat balance sheet, emissions, etc. An engineer should be able to develop or select a suitable test setup for the engine to be tested, depending on the testing objective, and also be able to carry out the testing to come up with the desired results and conclusions.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer –
'Understand parameters of IC engine performance testing.'

III. Course Level Learning Outcome (CO)

CO3 – Carryout test for the performance of an I.C. engine

IV. Laboratory Learning Outcome(s)

- Select the proper instrument to conduct a test.
- Measure the various parameters like temperature, pressure, fuel consumption, and water flow rate, using the I.C. engine test rig.

V. Relative Affective Domain Related Outcome(s)

- Follow safety practices.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background

Construction and working of four-stroke S.I. Engine –A four-stroke spark ignition engine completes its one operating cycle with four strokes of the piston and two revolutions of the crankshaft. The intake and exhaust valves are operated by the camshaft, which in turn is rotated by the crankshaft. The speed of the camshaft is half that of the crankshaft. When the piston moves from TDC to BDC and the intake valve is open, the fresh charge (atomized mixture of gasoline in air) is sucked into the cylinder, the exhaust valve being closed. The charge is compressed when the piston moves to TDC, both the valves being closed. A spark produced by a spark plug at the end of compression ignites the charge, thereby increasing pressure and

temperature in the combustion chamber. The piston is forced to move towards BDC, and power is said to be developed by the engine. With this movement of the piston, expansion of the combustion gases takes place. These gases are expelled out of the cylinder with the movement of the piston towards BDC, the exhaust valve being opened. The operating cycle is then repeated.

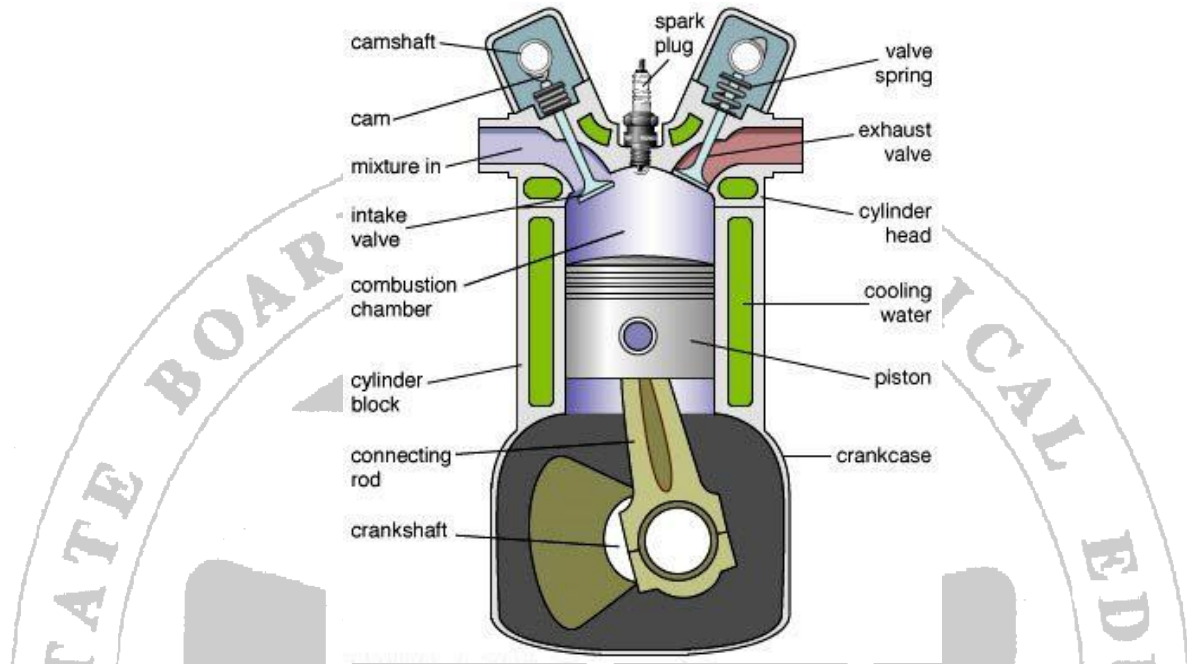


Figure 9.1 – Construction of four-stroke S. I. engine

Working of a four-stroke C.I. Engine –In a compression ignition engine, the fuel injector replaces the spark plug. The air is sucked in during the suction stroke, and it is compressed during the compression stroke. Due to high compression stroke, the compressed air temperature is so high that it becomes more than the self-ignition temperature of the diesel fuel. So, when the fuel is injected into the hot compressed air by the injector, it gets ignited. The piston is forced down by the high-pressure combustion gases, which means the generation of power. Finally, the gases are expelled out of the cylinder during the exhaust stroke to repeat the cycle.

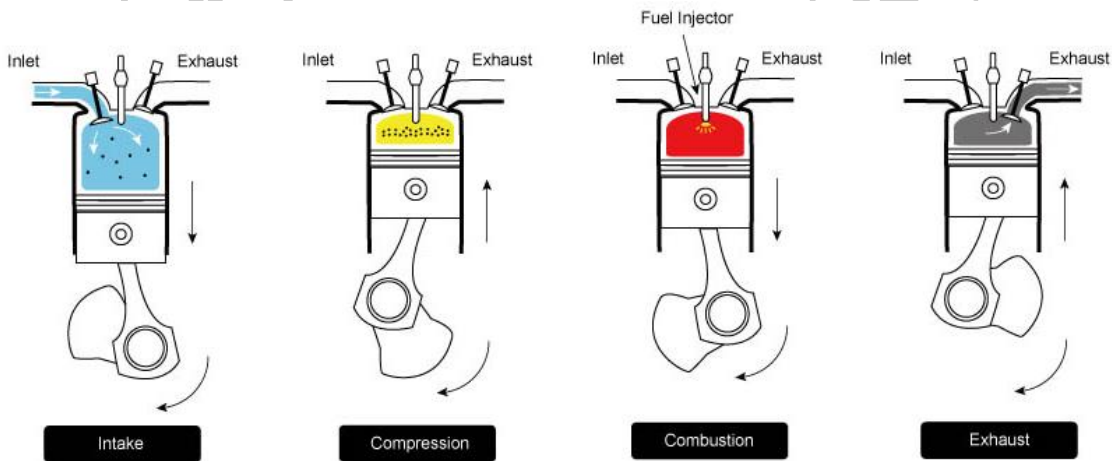


Figure No. 9.2 – Working of four-stroke C.I. engine

Need for I.C. Engine Test Rig – The Internal Combustion (I.C.) engine test rig is used to evaluate engine performance by measuring key parameters under controlled conditions. An I.C. engine is a heat engine where fuel combustion occurs inside the engine cylinder. It is broadly classified into spark ignition (SI) and compression ignition (CI) types, operating on either a two-stroke or four-stroke cycle. Essential engine components include the cylinder, piston, crankshaft, connecting rod, valves, camshaft, and fuel injector or spark plug. The test rig helps determine performance metrics such as brake power (BP), indicated power (IP), friction power (FP), brake thermal efficiency, mechanical efficiency, and specific fuel consumption. Instruments like dynamometers, fuel flow meters, manometers, and tachometers are used to measure output power, fuel usage, airflow, and engine speed. Understanding these concepts allows for analysis of the engine's thermal and mechanical performance, and advanced experiments may include creating a heat balance sheet to study energy distribution within the system.

VII. Experimental setup

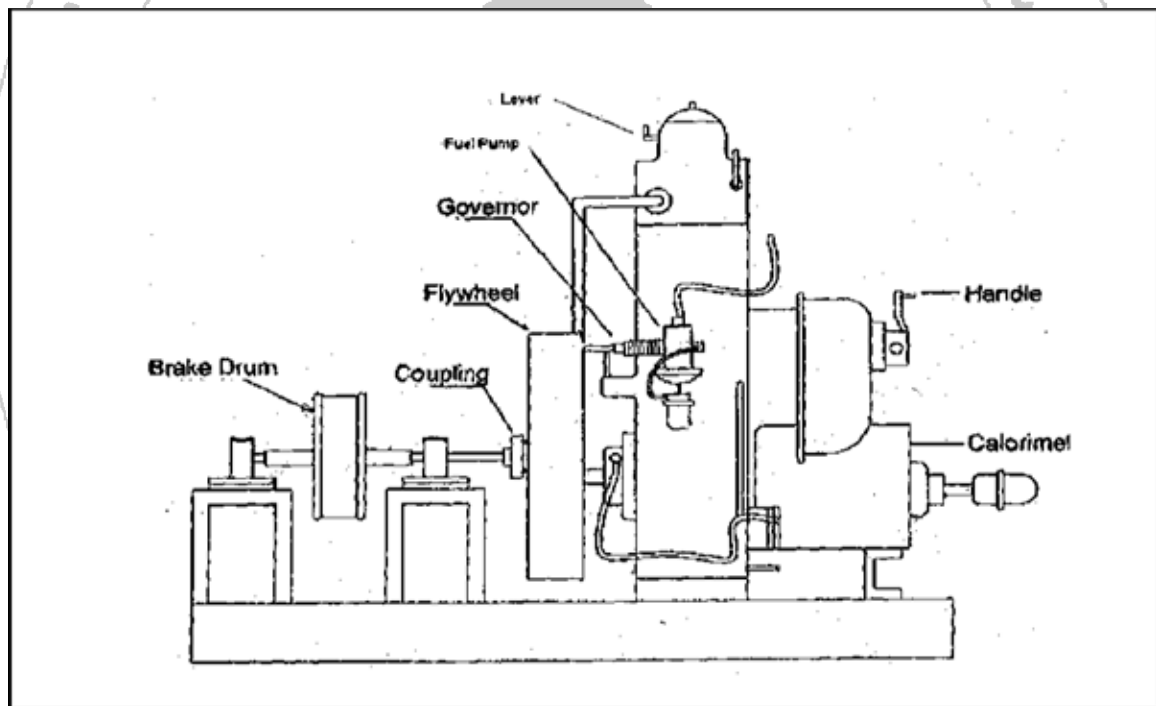


Figure 9.3 –Layout of Four-stroke engine test rig with rope brake dynamometer



Figure 9.4 - Four-stroke engine test rig with rope brake dynamometer

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Engine	Single cylinder or multi-cylinder (3or4), Four Stroke, Petrol / Diesel Engine, bore 80 mm, Stroke 100 mm, Power developed - 5 HP for single cylinder or as available for multi-cylinder engine.	1
2	Dynamometer (Any one type, as suitable)	Rope Brake with brake drum, D = 300 mm, rope dia. d = 15 mm, Hydraulic with constant, K = 2000, Eddy current with constant, K=200	1
3	Tachometer	Speed range 0 to 5000 rpm	1
4	Fuel gauge	Burette of 50 ml	1
5	Stopwatch	As available	1
6	Water flow meter	Turbine type	1
7	Thermocouple	RTD	5 to 6
8	Digital Temperature Indicator	Pt100RTD, s4-20 A range	1
9	Air box	400 mm x 400 mm x 500 mm	1
10	Orifice fitted to air box	Diameter of Orifice (do) = 14 mm	1
11	Water manometer	Glass U tube	1
12	Exhaust Gas Calorimeter	Shell and tube type with insulation	1

IX. Precautions to be Followed

- Check diesel, oil, and coolant levels before starting the engine.
- Ensure proper connections of the battery and high-tension distributor to spark plug cables.
- Don't tamper with ignition timing, distributor, governor, and fuel injector settings.
- Ensure supply of coolant/water to the engine and dynamometer.
- Stay safely away from moving/rotating components.
- Never stop the engine while under load, and never use the decompression lever to stop it.

X. Procedure

1. Fill up water in Manometer up to half of the manometer height.
2. Start the water supply for the engine jacket, brake drum, and exhaust gas calorimeter.
3. If found, remove air bubbles in the fuel pipe by opening the vent screw provided at the fuel pump.
4. Adjust the dynamometer load to zero, releasing the loading screw, the rope being tension free.
5. Start the engine - Lift the decompression lever at the side of the valve cover. Put the handle over the starting shaft and rotate the shaft. As the engine picks up sufficient speed, drop the decompression lever. The engine will start. Remove the handle immediately. Allow the engine to get stabilized.
6. As the engine picks up its rated speed, start water to the brake drum. If required, adjust the fuel supply to bring the engine to the desired test speed at which trials are to be conducted (further, all the readings are to be taken at this test speed).
7. Open the burette filling cock, take a sufficient amount of diesel in the burette, and close the cock.
8. Turn the selector cock to 'Burette' position and note down the time required to consume a certain amount of fuel (10 ml / 20 ml, 50 ml) with the help of the fuel gauge and stop watch, i.e., 't' seconds.
9. Note down the engine speed with tachometer.
10. Take manometer readings h_1 and h_2 .
11. Measure Time (T_w in min) required for specific quantity ($Q_w = 10/20/50$ liters) of jacket cooling water on the water meter using a stopwatch.
12. Note down its inlet temperature ($t_1^\circ\text{C}$) and outlet temperature ($t_2^\circ\text{C}$) across the engine jacket.
13. Measure engine room temperature ($t_R^\circ\text{C}$)
14. Measure exhaust gas temperatures at the following locations:
 - i) Measure temperature of exhaust gases from the engine ($t_g^\circ\text{C}$)
 - ii) If the exhaust gas calorimeter is used, then measure,
 - (a) Temperature of water inlet to calorimeter ($t_{c1}^\circ\text{C}$)
 - (b) Temperature of water outlet from the calorimeter ($t_{c2}^\circ\text{C}$)
 - (c) Temperature of exhaust gas entering the calorimeter ($t_{g1}^\circ\text{C}$)
 - (d) Temperature of exhaust gas leaving the calorimeter ($t_{g2}^\circ\text{C}$)
15. All the readings taken in steps. 8 to 14 are for No load condition of engine. Note these readings in the Observation table in the column of No load.

16. Repeat the procedure to take all readings as in step nos. 8 to 14, increasingly putting brake load on the dynamometer as mentioned in the observation table, and note down those readings in their appropriate column.

Note: In case of a constant speed governor, the engine will attain the test speed after changing the dynamometer brake load. In case of a variable speed governor, adjust the fuel supply to bring the engine to the test speed at which the test is to be conducted.

XI. Observations and calculations

- Diameter of brake drum, $D = \dots\dots\dots \text{ mm} = \dots\dots\dots \text{ m}$
- Diameter of rope, $d = \dots\dots\dots \text{ mm} = \dots\dots\dots \text{ m}$
- Effective radius of brake drum, $R_e = (D+d) / 2 = (\dots\dots\dots + \dots\dots\dots) / 2 = \dots\dots\dots \text{ m}$
- Diameter of orifice of air box, $d_o = \dots\dots\dots \text{ mm} = \dots\dots\dots \text{ m}$
- Specific gravity of fuel = $\dots\dots\dots$

Observation Table

Sr.No.	Load condition Particulars	No load	1/4th load	Half Load	3/4th Load	Full Load
1	Weight(W) in kg					
2	Spring balance reading (S) in kg (in case of rope brake dynamometer)					
3	Speed (N) in rpm					
4	Time taken to consume a specific quantity (10ml, 20 ml as suitable of fuel (t) in sec.					
5	Jacket water inlet temp, (t1) in °C					
6	Jacket water outlet temp. (t2) in °C					
7	Time (Tw) required for (Qw =10/20/50 liter) of jacket cooling water in min					
8	Exhaust gas temp. (tq) in °C					
9	Engine room temp. (tr) in °C					
10	Water manometer reading: hw, cm	h_1				
		h_2				
11	Time (Twc) required for (Qwc =10/20/50 liter) of calorimeter cooling water in min					
12	Temperature of water inlet from calorimeter(tc ₁) in °C					
13	Temperature of water outlet from calorimeter(tc ₂) in °C					
14	Temperature of exhaust gases entering calorimeter (tg ₁) in °C					
15	Temperature of exhaust gases leaving calorimeter (tg ₂) in °C					

Calculations Table

Sr.No.	Particulars	Formulae	No load	1/4 th load	Half Load	3/4 th Load	Full Load
1	Weight(W) in N	(W in kg x 9.81)					
2	Spring balance reading (S) in N (in case of rope brake dynamometer)	(Sinkgx9.81)					
3	Quantity of fuel consumed (m _{fc}) in lit/sec	Sp. Quantity of fuel(ml) / 1000 x t					
	Quantity of fuel consumed (m _{fc}) in lit/hr.	(m _{fc}) in lit/sec x 3600					
	Mass of Fuel consumed (m _f) in kg/hr.	(m _{fc} in lit/hr.x specific gravity of fuel)					
4	Mass of jacket cooling water (m _w) in kg/min	Q _w (10/20/50) / T _w					
5	Manometer difference or water head (m _w) in meters	$\frac{(h_2-h_1)}{100}$					
6	Mass of water supplied to exhaust gas calorimeter (m _{wc}) in kg/min	Q _{wc} (10/20/50) / T _{wc}					

Calculations for mass flow rate of air (at full load)

1. Density of air

It is calculated from the general gas equation as follows:

$$P_a \times V_a = m_a \times R_a \times T_r$$

$$P_a = \text{Atmospheric Pressure} = 1.01325 \text{ bar} = 1.01325 \times 10^5 \text{ N/m}^2$$

Where, m_a = mass of air

R_a = Characteristic gas constant = 287 J/kg

$$\text{So, } m_a = P_a \times V_a / (R_a \times T_r)$$

Now, density of air, ρ_a = m_a / V_a = P_a / [R_a x T_r], where P_a is in N/m².

$$= P_a / [R_a \times (t_1 + 273)] = \dots\dots\dots / [287 \times (\dots\dots + 273)]$$

$$\rho_a = \dots\dots\dots \text{ kg/m}^3$$

2. Water manometric head

$$h_w = h_1 - h_2 = \dots\dots\dots$$

$$h_w = \dots\dots\dots \text{ mm of water} = \dots\dots\dots \text{ m of water}$$

3. Air ahead causing the flow of air

$h_a = h_w \times \rho_w / \rho_a$ Where, $\rho_w =$ Density of water = 1000 kg/m³

So, $h_a = (\dots \times 1000) / (\dots) = \dots$ m of air

4. Actual volume of air consumed by the engine

Area of Orifice, $a_o = (\pi/4) d_o^2 = (\pi/4) \times (\dots)^2$

$a_o = \dots$ m²

$Q_a = C_d \times a_o \times \sqrt{2gh_a}$ m³/s

$Q_a = \dots \times \dots \times \sqrt{2 \times 9.81 \times \dots}$ m³/s

$Q_a = \dots$ m³/s

5. Mass of air

$m_a = \rho_a \times Q_a = \dots \times \dots = \dots$ kg/s

$m_a = \dots$ kg/s $\times 3600 = \dots$ kg/hr.

XII. Results

At full load of \dots N

1. Rise in jacket cooling water temperature, $(t_2 - t_1) = \dots$ °C.
2. Exhaust gas temperature, $t_g = \dots$ °C.
3. Mass flow rate of air, $m_a = \dots$ kg/hr.
4. Mass flow rate of water, $m_w = \dots$ kg/hr.
5. Fuel consumption, $m_f = \dots$ kg/hr.

XIII. Interpretation of Results

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XIV. Conclusions and Recommendation

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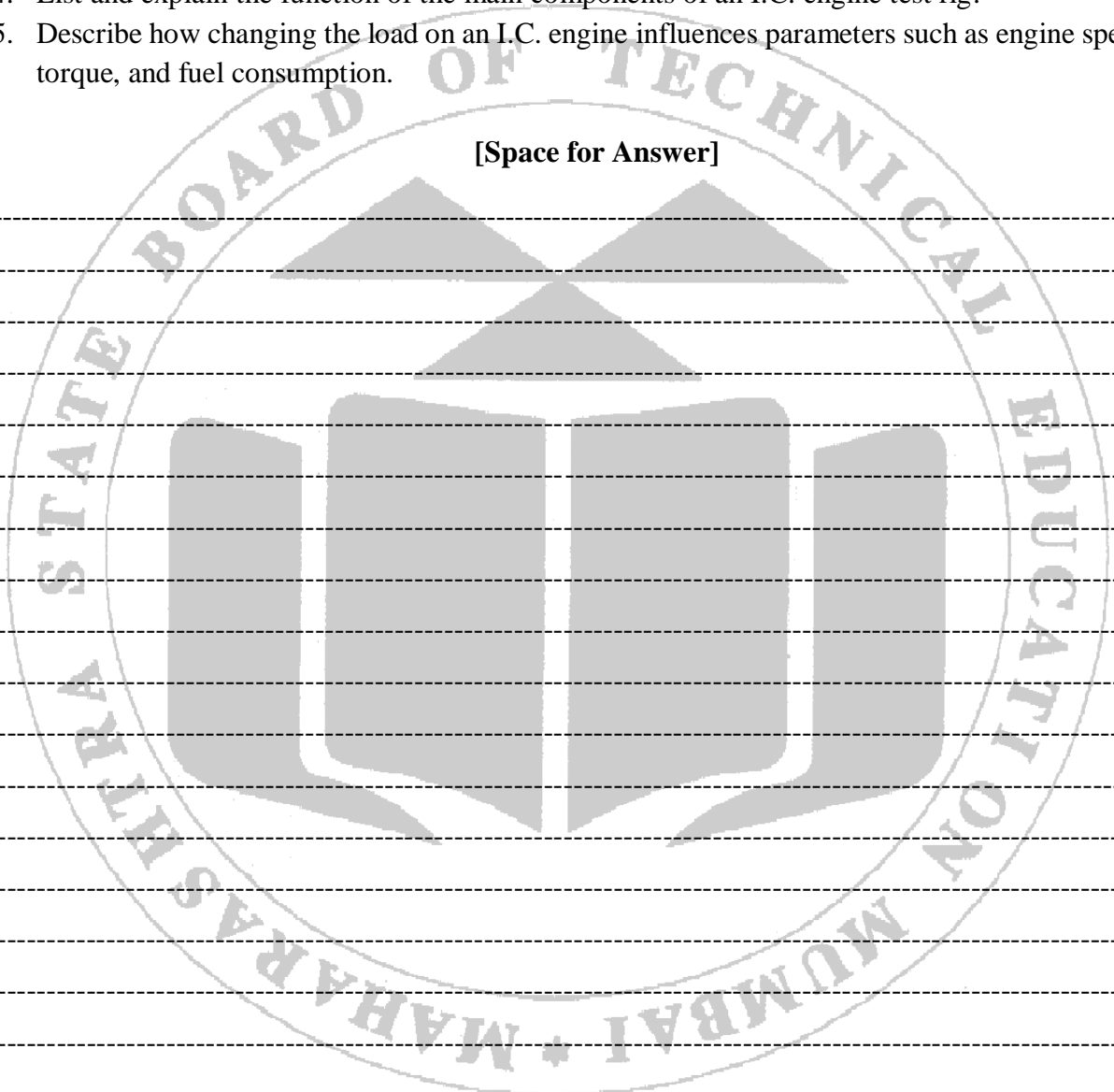
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XV. Practical Related Questions

Note: Below given are a few sample questions for reference. Teachers must design more such questions to ensure the achievement of identified CO.

1. State the advantages and limitations of the rope brake dynamometer for its use in the I.C. engine test rig.
2. Comment on the range of air-fuel ratio in S.I. Engine and that in C.I. Engine.
3. State the reason for the camshaft speed to be half that of the crankshaft.
4. List and explain the function of the main components of an I.C. engine test rig.
5. Describe how changing the load on an I.C. engine influences parameters such as engine speed, torque, and fuel consumption.

[Space for Answer]



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XVI. References / Suggestions for Further Reading

- Parts and working of S.I. Engine: https://www.youtube.com/watch?v=DKF5dKo_r_Y
- Working of diesel engine: <https://www.youtube.com/watch?v=fTAUq6G9apg>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the Equipment and Measuring Instruments	20%
2	Noting the Observations	20%
3	Calculations of the parameters	20%
Product Related (10 Marks)		(40%)
4	Interpretation of the result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 10: Test on I.C. engine test rig Part – I

I. Practical Significance

Conducting trials on an internal combustion (I.C.) engine is crucial for evaluating its performance in terms of useful output, which is the power developed by the engine. Although the engine develops power through the expansion of combustion gases in its cylinder, it is often important to know how much power is available on the engine crankshaft. This is because the engine crankshaft provides the driving power to the power-consuming devices and equipment. Further, the engine testing enables optimization of combustion processes, tuning of ignition timing, setting appropriate air-fuel ratios, and benchmarking different engine configurations for comparative studies. By analyzing wear and tear over prolonged testing, engineers can enhance reliability, reduce maintenance costs, and improve overall engine longevity. Thus, making engine trials becomes an indispensable step in engine development and refinement.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer: ‘Analyze engine performance based on power output and related curves.’

III. Course Level Learning Outcome (CO)

CO3 - Carryout test for the performance of an I.C. engine.

IV. Laboratory Learning Outcome(s)

- Calculate the various parameters like Brake power, Frictional power, and Mechanical efficiency.
- Draw the performance curves.

V. Relative Affective Domain Related Outcome(s)

- Follow safety practices.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background

Engine Power Terms:

a) Indicated Power – It is the power developed by the engine in its cylinder by virtue of the expansion of the combustion gases. It is obtained by using the Engine Indicator, with the help of the following equation.

$$P_I = p_m \times L \times A \times n \times K \dots \text{ in W}$$

Where, p_m – Mean effective pressure in the cylinder during expansion stroke in N/m^2 .

L – Stroke length of the cylinder in m.

A – Cross-sectional area of the cylinder in m^2 .

n – Number of firings per second in 1/s.

K – Number of engine cylinders.

- b) Brake Power – It is the useful power available at the engine crankshaft. It is obtained by a suitable dynamometer connected to the engine crankshaft.

$$P_B = 2\pi \times N \times T / 60 \dots\dots \text{ in W (for a Rope Brake Dynamometer).}$$

Where N – Engine speed in rpm.

T – Brake torque on engine in N-m.

- c) Friction Power – It is the power lost to overcome the friction in the parts of the engine and also the engine's pumping losses. It is calculated by difference as

$$P_{FP} = P_I - P_B$$

It can also be estimated by conducting the Morse Test only on a multi-cylinder engine.

Mechanical Efficiency –

Mechanical efficiency of the engine is the ratio of its brake power to the indicated power. It reflects the frictional losses in the engine, such that the higher the mechanical efficiency, the lower the power lost in friction by the engine.

$$\eta_{\text{mech}} = P_B / P_I$$

Engine performance curves –

- a) Brake power Vs engine load

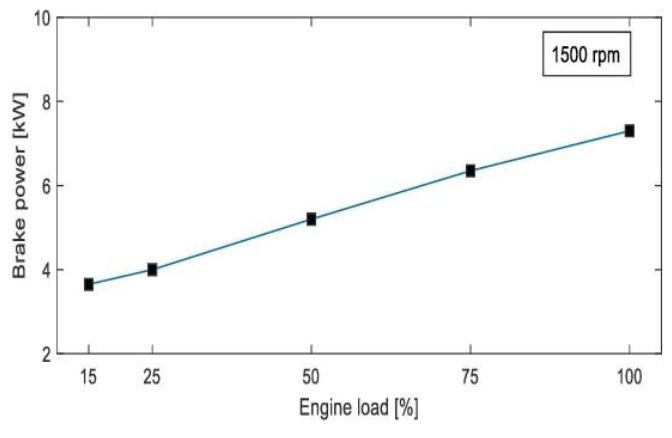


Figure 10.1 – Variation of engine brake power with engine load

- b) Engine power and torque Vs engine speed

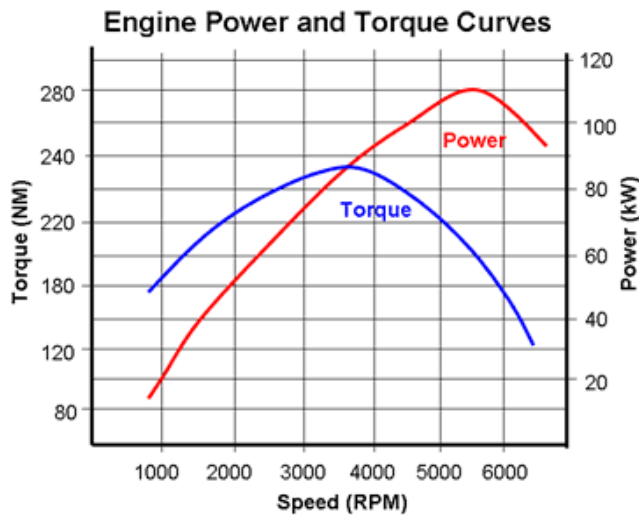


Figure 10.2 – Variation of engine power and torque with engine speed

VII. Experimental setup

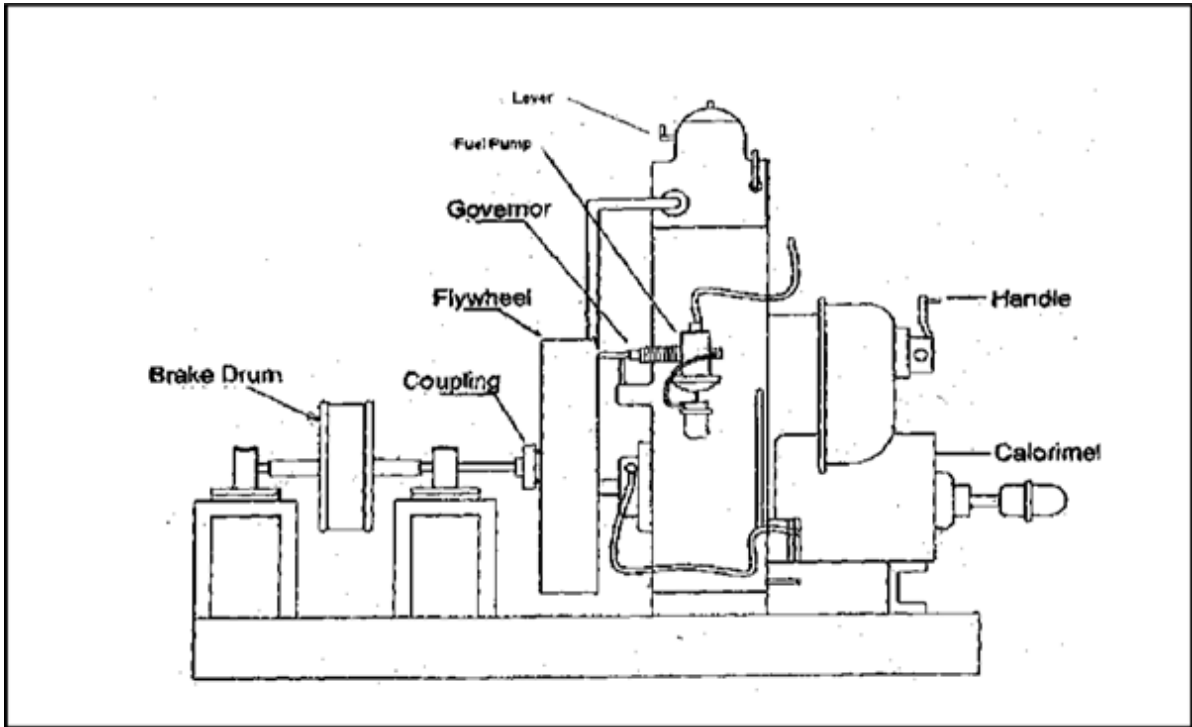


Figure 10.3 - Four-stroke engine test rig with rope brake dynamometer



Figure 10.4 - Four-stroke engine test rig with rope brake dynamometer

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Engine	Single cylinder or multi-cylinder (3or4), Four Stroke, Petrol / Diesel Engine, bore 80 mm, Stroke 100 mm, Power developed - 5 HP for single cylinder or as available for multi-cylinder engine.	1
2	Dynamometer (Any one type, as suitable)	Rope Brake with brake drum, D = 300 mm, rope dia. d = 15 mm, Hydraulic with constant, K = 2000, Eddy current with constant, K=200	1
3	Tachometer	Speed range 0 to 5000 rpm	1
4	Fuel gauge	Burette of 50 ml	1
5	Stopwatch	As available	1
6	Water flow meter	Turbine type	1
7	Thermocouple	RTD	5 to 6
8	Digital Temperature Indicator	Pt100RTD, s4-20 A range	1
9	Air box	400 mm x 400 mm x 500 mm	1
10	Orifice fitted to air box	Diameter of Orifice (do) = 14 mm	1
11	Water manometer	Glass U-tube	1
12	Exhaust Gas Calorimeter	Shell and tube type with insulation	1

IX. Precautions to be Followed

- Check diesel, oil and coolant levels before starting the engine.
- Ensure proper connections of the battery and high-tension distributor to spark plug cables.
- Don't tamper with ignition timing, distributor, governor and fuel injector settings.
- Ensure supply of coolant / water to the engine and dynamometer.
- Stay safely away from moving / rotating components.
- Never stop the engine in load and never use the decompression lever for to stop it.

X. Procedure

1. Fill up water in Manometer up to half of the manometer height.
2. Start the water supply for engine jacket, brake drum and exhaust gas calorimeter.
3. If found, remove air bubbles in fuel pipe by opening the vent screw provided at the fuel pump.
4. Adjust dynamometer load to zero, releasing the loading screw, rope being tension free.
5. Start the engine - Lift up decompression lever, at the side of the valve cover. Put the handle over the starting shaft and rotate the shaft. As engine picks up sufficient speed, drop the decompression lever. The engine will start. Remove the handle immediately. Allow the engine to get stabilized.
6. As engine picks up its rated speed, start water to the brake drum. If required, adjust the fuel supply in order to bring the engine to the desired test speed at which trials to be conducted (further, all the readings are to be taken at this test speed).

7. Open the burette filling cock, take a sufficient amount of diesel in the burette, and close the cock.
8. Turn the selector cock to 'Burette' position and note down the time required to consume a certain amount of fuel (10 ml / 20 ml, 50 ml) with the help of the fuel gauge and stop watch, i.e., 't' seconds.
9. Note down the engine speed with tachometer.
10. Take manometer readings h_1 and h_2 .
11. Measure Time (T_w in min) required for specific quantity ($Q_w = 10/20/50$ liters) of jacket cooling water on the water meter using a stopwatch.
12. Note down its inlet temperature ($t_1^\circ\text{C}$) and outlet temperature ($t_2^\circ\text{C}$) across the engine jacket.
13. Measure engine room temperature ($t_r^\circ\text{C}$)
14. Measure exhaust gas temperatures at the following locations:
 - i) Measure temperature of exhaust gases from the engine ($t_g^\circ\text{C}$)
 - ii) If the exhaust gas calorimeter is used, then measure,
 - (a) Temperature of water inlet to calorimeter ($t_{c_1}^\circ\text{C}$)
 - (b) Temperature of water outlet from the calorimeter ($t_{c_2}^\circ\text{C}$)
 - (c) Temperature of exhaust gas entering the calorimeter ($t_{g_1}^\circ\text{C}$)
 - (d) Temperature of exhaust gas leaving the calorimeter ($t_{g_2}^\circ\text{C}$)
15. All the readings taken in step nos. 8 to 14 are for No load condition of the engine. Note these readings in the Observation table in the column of No load.
16. Repeat the procedure to take all readings as in step nos. 8 to 14 increasingly putting brake load on the dynamometer as mentioned in the observation table and note down those readings in its appropriate column.

Note: In case of constant speed governor, engine will attain the test speed after changing the dynamometer brake load. In case of variable speed governor, adjust the fuel supply to bring the engine to test speed at which test is to be conducted.
17. Determine Frictional Power (F.P.) as follows
 - i) On graph paper X axis take Brake Power (BP) in KW to some scale.
 - ii) On Y axis take mass of fuel consumed in Kg / min (mf) to some scale.
 - iii) Mark the points showing X and Y co-ordinates i.e. respective BP and mf on graph.
 - iv) Draw straight line passing through maximum no. of points on graph.
 - v) Intercept on negative X axis represents Friction Power (FP). As the trial is conducted at constant speed, FP is assumed to be same for all the load values.
 - vi) Enter FP obtained as above for all the loads, in the Sr. No. 9 of Calculations Table.
18. Calculate indicated power and mechanical efficiency.

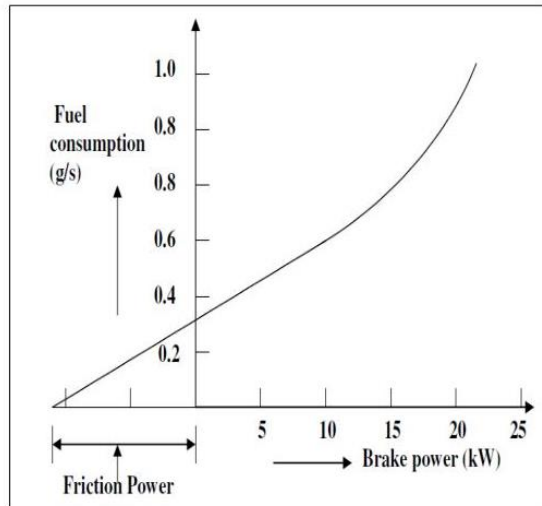


Figure 10.5 – Willan’s line method for friction power

XI. Observations and calculations

- Diameter of brake drum, $D = \dots\dots\dots \text{mm} = \dots\dots\dots \text{m}$
- Diameter of rope, $d = \dots\dots\dots \text{mm} = \dots\dots\dots \text{m}$
- Effective radius of brake drum, $R_e = (D+d) / 2 = (\dots\dots\dots + \dots\dots\dots) / 2 = \dots\dots\dots \text{m}$
- Diameter of orifice of air box, $d_o = \dots\dots\dots \text{mm} = \dots\dots\dots \text{M}$
- Specific gravity of fuel = $\dots\dots\dots$

Observation Table

Sr. No.	Load condition Particulars	No load	1/4 th load	Half Load	3/4 th Load	Full Load
1	Weight(W)in kg					
2	Spring balance reading(S) in kg (in case of rope brake dynamometer)					
3	Speed(N)in rpm					
4	Time taken to consume a specific quantity (10ml,20ml) of fuel(t)in sec					

Calculations Table

Sr.No.	Particulars	Formulae	No load	1/4 th load	Half Load	3/4 th Load	Full Load
1	Weight(W)inN	$(W \text{ in kg} \times 9.81)$					
2	Spring balance reading (S) in N (in case of rope brake dynamometer)	$(\text{Sink} \times 9.81)$					

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XII. Results

At full load of N,
Brake power, $P_B =$ kW.
Frictional power, $P_F =$ kW.
Indicated power, $P_I =$ kW.
Mechanical efficiency = $\eta_{mech} =$

XIII. Interpretation of Results

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XIV. Conclusions and Recommendations

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XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Draw a graph of brake power Vs load based on the test conducted.
2. Draw a graph of mechanical efficiency Vs load based on the test conducted.
3. Explain the term ‘pumping losses’ of the engine.

XVI. References / Suggestions for Further Reading

- I.C. engine performance parameters: <https://www.youtube.com/watch?v=uLqdB121Rk0>
- Pumping losses of engine and engine braking: <https://www.youtube.com/watch?v=fB7GXjqQEHY>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the Equipment and Measuring Instruments	10%
2	Noting the Observations	10%
3	Calculations of the parameters	40%
Product Related (10 Marks)		(40%)
4	Interpretation of the result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 11: Test on I.C. Engine Test Rig (Part II)

I. Practical Significance

In any I.C. Engine, the energy input is the heat liberated by the combustion of fuel in the engine combustion chamber, and the desirable output is the mechanical power available at the engine crankshaft, i.e., brake power. The brake thermal efficiency, which is the ratio of engine brake power to the heat energy input, is a more realistic performance parameter of any engine, such that we expect a greater amount of fuel combustion heat energy to be converted into the brake power. This depends on the amount of losses of heat energy in the engine, such that the lesser the losses, more will be the brake thermal efficiency. These losses include the heat carried away by the cooling water circulated in the engine cylinder and head, heat carried away by the engine exhaust gases, power lost to overcome the engine parts' friction, engine pumping losses, radiation heat loss, etc. Engine testing to estimate the distribution of heat energy supplied by the combustion of fuel into the above-mentioned parameters becomes essential in view of reducing the heat energy and power losses, thereby improving engine brake thermal efficiency. This distribution is tabulated in a sheet called Heat Balance Sheet, which provides the guidelines for improvements in the engine design, materials, manufacturing, operation, and maintenance to achieve improved brake thermal efficiency, reducing the fuel consumption and pollution.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer: 'Analyze the engine performance pertaining to the heat utilization.'

III. Course Level Learning Outcome (CO)

CO3 – Carryout test for the performance of an I.C. engine.

IV. Laboratory Learning Outcome(s)

- Perform the test using I.C. engine test rig to measure the various parameters like temperature, pressure, fuel consumption, water flow rate, etc.
- Prepare a heat balance sheet.

V. Relative Affective Domain-related Outcome(s)-

- Follow safety practices.
- Demonstrate working as a leader/a team member
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Minimum Theoretical Background with diagram

1. Thermal efficiency of engine:

- a) Indicated thermal efficiency – It is the ratio of indicated power of the engine to the heat energy supplied by the combustion of fuel in combustion chamber.

$$\text{Given by, } \eta_{ith} = I.P. / H_F$$

b) Brake thermal efficiency – It is the ratio of brake power of the engine to the heat energy supplied by the combustion of fuel in combustion chamber.

Given by, $\eta_{ith} = B.P. / H_F$

2. Brake Specific fuel consumption (BSFC) –

It is the rate of fuel consumption of the engine per unit brake power developed by the engine. Given by, $BSFC = mf / P_{BP}$

Usually, the units for fuel consumption and brake power used to express BSFC are kg/hr. and kW respectively.

3. Heat Balance Sheet

HEATCREDIT (or Heat Supplied)			HEATDEBIT (or Heat Expenditure)		
Heat supplied	kJ/min	%	Heat Expenditure	kJ/min	%
Heat supplied by combustion of fuel (H_F)		100	A) Heat equivalent to Brake Power (H_{BP})		
			B) Heat carried by jacket water (H_W)		
			C) Heat carried by exhaust gases (H_G)		
			D) Heat lost in friction (H_{FP})		
			E) Unaccounted heat loss (H_U)		
Total		100			100

VII. Experimental setup

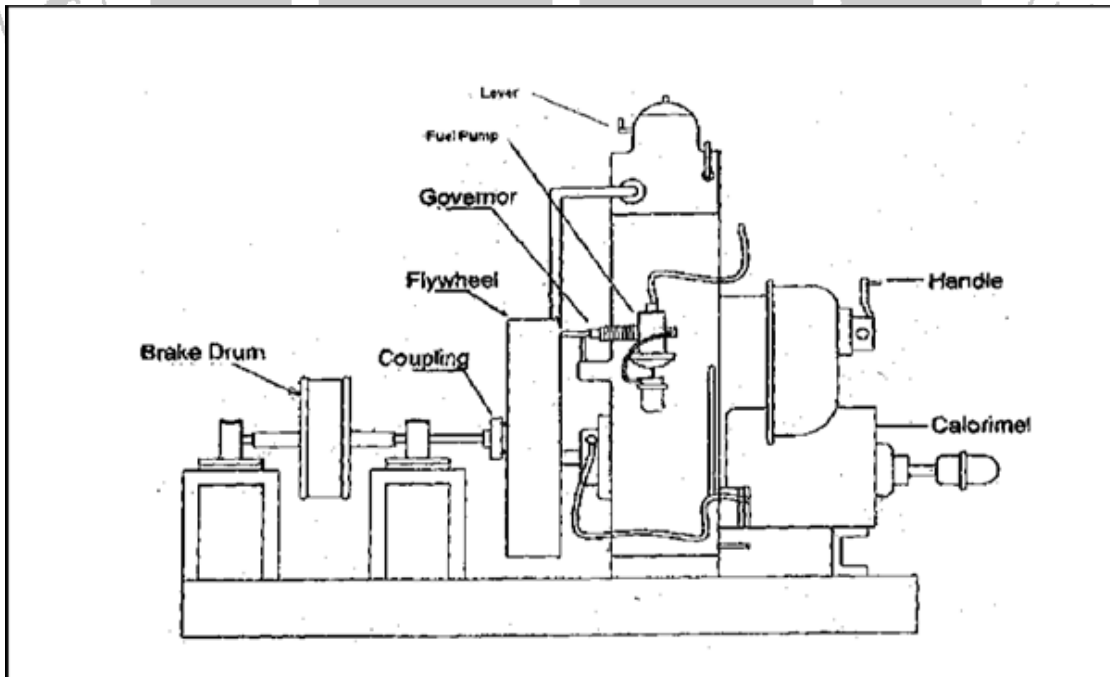


Figure 11.1 - Four-stroke engine test rig with rope brake dynamometer



Figure 11.2 - Four-stroke engine test rig with rope brake dynamometer

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Engine	Single cylinder or multi-cylinder (3 or 4), Four Stroke, Petrol / Diesel Engine, bore 80 mm, Stroke 100 mm, Power developed - 5 HP for single cylinder or as available for multi-cylinder engine.	1
2	Dynamometer (Any one type, as suitable)	Rope Brake with brake drum, D = 300 mm, rope dia. d = 15 mm, Hydraulic with constant, K = 2000, Eddy current with constant, K=200	1
3	Tachometer	Speed range 0 to 5000 rpm	1
4	Fuel gauge	Burette of 50 ml	1
5	Stopwatch	As available	1
6	Water flow meter	Turbine type	1
7	Thermocouple	RTD	5 to 6
8	Digital Temperature Indicator	Pt100RTD, s4-20 A range	1
9	Air box	400 mm x 400 mm x 500 mm	1
10	Orifice fitted to air box	Diameter of Orifice (do) = 14 mm	1
11	Water manometer	Glass U-tube	1
12	Exhaust Gas Calorimeter	Shell and tube type with insulation	1

Note: Specifications mentioned are for reference only.

IX. Precautions to be Followed

- Check diesel, oil, and coolant levels before starting the engine.
- Ensure proper connections of the battery and high-tension distributor to spark plug cables.
- Don't tamper with ignition timing, distributor, governor, and fuel injector settings.
- Ensure supply of coolant/water to the engine and dynamometer.
- Stay safely away from moving/rotating components.
- Never stop the engine while under load, and never use the decompression lever to stop it.

X. Procedure

1. Fill up water in Manometer up to half of the manometer height.
2. Start the water supply for the engine jacket, brake drum, and exhaust gas calorimeter.
3. If found, remove air bubbles in the fuel pipe by opening the vent screw provided at the fuel pump.
4. Adjust the dynamometer load to zero, releasing the loading screw, the rope being tension free.
5. Start the engine - Lift the decompression lever at the side of the valve cover. Put the handle over the starting shaft and rotate the shaft. As the engine picks up sufficient speed, drop the decompression lever. The engine will start. Remove the handle immediately. Allow the engine to get stabilized.
6. As the engine picks up its rated speed, start water to the brake drum. If required, adjust the fuel supply to bring the engine to the desired test speed at which trials are to be conducted (further, all the readings are to be taken at this test speed).
7. Open the burette filling cock, take a sufficient amount of diesel in the burette, and close the cock.
8. Turn the selector cock to 'Burette' position and note down the time required to consume a certain amount of fuel (10 ml / 20 ml 50 ml) with the help of fuel gauge and stop watch, i.e., 't' seconds.
9. Note down the engine speed with tachometer.
10. Take manometer readings h_1 and h_2 .
11. Measure Time (T_w in min) required for specific quantity ($Q_w = 10/20/50$ liters) of jacket cooling water on the water meter using a stopwatch.
12. Note down its inlet temperature (t_1 °C) and outlet temperature (t_2 °C) across the engine jacket.
13. Measure engine room temperature (t_R °C)
14. Measure exhaust gas temperatures at the following locations:
 - i) Measure temperature of exhaust gases from the engine (t_g °C)
 - ii) If the exhaust gas calorimeter is used, then measure,
 - (a) Temperature of water inlet to calorimeter (t_{c1} °C)
 - (b) Temperature of water outlet from the calorimeter (t_{c2} °C)
 - (c) Temperature of exhaust gas entering the calorimeter (t_{g1} °C)
 - (d) Temperature of exhaust gas leaving the calorimeter (t_{g2} °C)
15. All the readings taken in step nos. 8 to 14 are for No load condition of the engine. Note these readings in the Observation table in the column of No load.

16. Repeat the procedure to take all readings as in steps nos. 8 to 14, increasingly putting brake load on the dynamometer as mentioned in the observation table, and note down those readings in their appropriate column.

Note: In case of a constant speed governor, engine will attain the test speed after changing the dynamometer brake load. In case of a variable speed governor, adjust the fuel supply to bring the engine to the test speed at which the test is to be conducted.

17. Determine Frictional Power (F.P.) as follows

- i) On graph paper, on the X axis, take Brake Power (BP) in KW to some scale.
- ii) On the Y axis, take the mass of fuel consumed in Kg/min (mf) to some scale.
- iii) Mark the points showing X and Y co-ordinates, i.e., respective BP and mf on the graph.
- iv) Draw a straight line passing through the maximum no. of points on the graph.
- v) Intercept on the negative X axis represents Friction Power (FP). As the trial is conducted at constant speed, FP is assumed to be the same for all the load values.
- vi) Enter FP obtained as above for all the loads, in Sr. No. 9 of the Calculations Table.

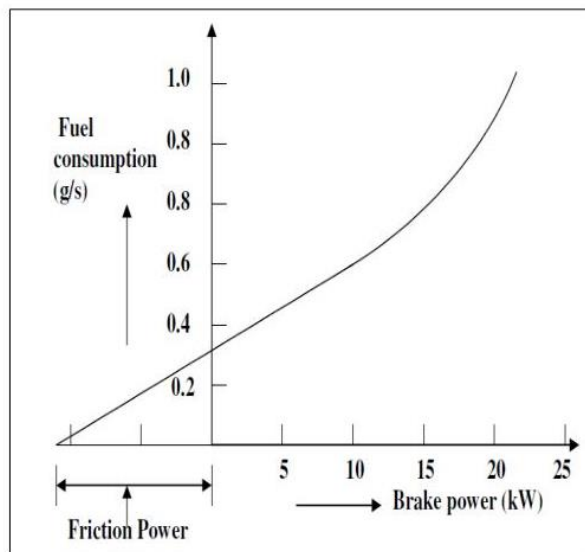


Figure 11.3 – Willan’s line method for friction power

18. Prepare a heat balance sheet on a minute and percentage basis for any one brake load other than zero, preferably for full load.

XI. Observations and calculations

- Diameter of brake drum, $D = \dots\dots\dots \text{ mm} = \dots\dots\dots \text{ m}$
- Diameter of rope, $d = \dots\dots\dots \text{ mm} = \dots\dots\dots \text{ m}$
- Effective radius of brake drum, $R_e = (D+d) / 2 = (\dots\dots\dots + \dots\dots\dots) / 2 = \dots\dots\dots \text{ m}$
- Diameter of orifice of air box, $d_o = \dots\dots\dots \text{ mm} = \dots\dots\dots \text{ M}$
- Specific gravity of fuel = $\dots\dots\dots$

Observation Table:

Sr.No.	Load condition Particulars	No load	1/4 th load	Half Load	3/4 th Load	Full Load
1	Weight(W) in kg					
2	Spring balance reading(S)in kg (in case Of rope brake dynamometer)					
3	Speed(N)in rpm					
4	Time taken to consume a specific quantity (10ml,20ml as suitable fuel (t) in sec					
5	Jacket water inlet temp, (t ₁) in°C					
6	Jacket water outlet temp.(t ₂) in°C					
7	Time (T _w) required for (Q _w =10/20/50 liter) of jacket cooling water in min					
8	Exhaust gas temp.(t _q)in°C					
9	Engine room temp.(t _r)in°C					
10	Water manometer reading h _w , cm	h ₁				
		h ₂				
11	Time (T _{wc}) required for (Q _{wc} =10/20/50 liter) of calorimeter cooling water in min					
12	Temp, of water inlet from calorimeter (t _{c1})in°C					
13	Temp, of water outlet from calorimeter (t _{c2})in°C					
14	Temp, of exhaust gases entering calorimeter(t _{g1})in°C					
15	Temp, of exhaust gases leaving calorimeter(t _{g2})in°C					

Calculations Table

Sr.No.	Particulars	Formulae	No load	1/4 th load	Half Load	3/4 th Load	Full Load
1	Weight(W) in N	(W in kg x 9.81)					
2	Spring balance reading (S) in N (in case of rope brake dynamometer)	(S in kg x 9.81)					

Sr.No.	Particulars	Formulae	No load	1/4 th load	Half Load	3/4 th Load	Full Load
3	Speed (N) in rpm						
4	Brake Power (B.P.) in kW - For a rope brake dynamometer	$\frac{2(w-s) \pi R_c N}{60 \times 1000}$					
	For a hydraulic dynamometer	$\frac{W \times N}{K}$					
	For the Eddy Current dynamometer	-----					
5	Quantity of fuel consumed (m _{fc}) in lit/sec	$\frac{\text{Sp. Quantity of fuel (ml)}}{1000 \times t}$					
6	Mass of jacket cooling water (m _w) in kg/min	$Q_w (10/20/50) / T_w$					
7	Manometer difference or water head (mw) in meters	$\frac{(h_2 - h_1)}{100}$					
8	Mass of Fuel consumed (m _f) in kg/min	$\frac{(m_{fc} \times \text{sp.gr. of fuel})}{X 60}$					
9	Frictional Power (F.P.) in kW	Refer to step no. 17 for the determination of FP					
10	Indicated Power (I.P.) in kW	(BP + FP)					
11	Mechanical Efficiency η _{mech} in (%)	(B.P. / I.P.) x 100					
12	Mass of water supplied to exhaust gas calorimeter (m _{wc}) in kg/min	$Q_{wc} (10/20/50) / T_{wc}$					

Space for the additional calculations required as per the above table:

B) Heat carried away by Jacket cooling water (H_{cw})

$$H_W = (m_w) \times C_{pw} \times (t_2 - t_1)$$

$$= (\dots\dots\dots) \times 4.187 \times (\dots\dots\dots - \dots\dots\dots)$$

$$H_W = \dots\dots\dots \text{kJ/min.}$$

C) Heat carried away by exhaust gases (H_g)(By two methods)

i) By using Air box method,

First, determine the mass of exhaust gas as follows,

Mass of air, $m_a = \rho_a \times Q_a = \dots\dots\dots$ equation(i)

a) Density of air is calculated from the general gas equation as follows:

$$P_a \times V_a = m_a \times R_a \times T_r$$

$$P_a = \text{Atmospheric Pressure} = 1.01325 \text{ bar} = 1.01325 \times 10^5 \text{ N/m}^2$$

m_a = mass of air

R_a = Characteristic gas constant = 287 J/kg

$$\text{So, } m_a = P_a \times V_a / (R_a \times T_r)$$

Now, density of air, $\rho_a = m_a / V_a = P_a / [R_a \times T_r]$, where P_a is in N/m^2 .

$$= P_a / [R_a \times (t_1 + 273)]$$

$$= \dots\dots\dots / [287 \times (\dots\dots\dots + 273)]$$

$$\rho_a = \dots\dots\dots \text{ kg/m}^3$$

b) Water manometric head

$$h_w = h_1 - h_2 = \dots\dots\dots$$

$$h_w = \dots\dots\dots \text{ mm of water} = \dots\dots\dots \text{ m of water}$$

c) Air ahead causing the flow of air

$$h_a = h_w \times \rho_w / \rho_a \text{ Where, } \rho_w = \text{Density of water} = 1000 \text{ kg/m}^3$$

$$\text{Therefore, } h_a = (\dots\dots\dots \times 1000) / (\dots\dots\dots)$$

$$= \dots\dots\dots \text{ m of air}$$

d) Actual volume of air consumed by the engine

Area of Orifice, $a_o = (\pi/4) d_o^2 = (\pi/4) \times (\dots\dots\dots)^2$

$a_o = \dots\dots\dots \text{ m}^2$

$Q_a = C_d \times a_o \times \sqrt{2gh_a} \text{ m}^3/\text{s}$

$Q_a = \dots\dots\dots \times \dots\dots\dots \times \sqrt{(2 \times 9.81 \times \dots\dots\dots)} \text{ m}^3/\text{s}$

So, $Q_a = \dots\dots\dots \text{ m}^3/\text{s}$

Now, mass of air, $m_a = \rho_a \times Q_a = \dots\dots\dots \times \dots\dots\dots = \dots\dots\dots \text{ kg/s}$

Or, $m_a = \dots\dots\dots \text{ kg/s} \times 60 = \dots\dots\dots \text{ kg/min.}$

Thus, mass of exhaust gases in kg/min = mass of air consumed in kg/min + mass of fuel consumed in kg/min

$M_g = m_a + m_f = \dots\dots\dots + \dots\dots\dots = \text{kg/min}$

Hence, heat carried away by exhaust gases,

$H_g = m_g \times C_{pg} \times (t_g - t_r) \dots\dots\dots (C_{pg} = 1.15 \text{ kJ/kg}^\circ\text{K,})$

$H_G = \dots\dots\dots \times \dots\dots\dots \times (\dots\dots\dots)$

$H_G = \dots\dots\dots \text{ kJ/min}$

ii) By using Exhaust Gas Calorimeter

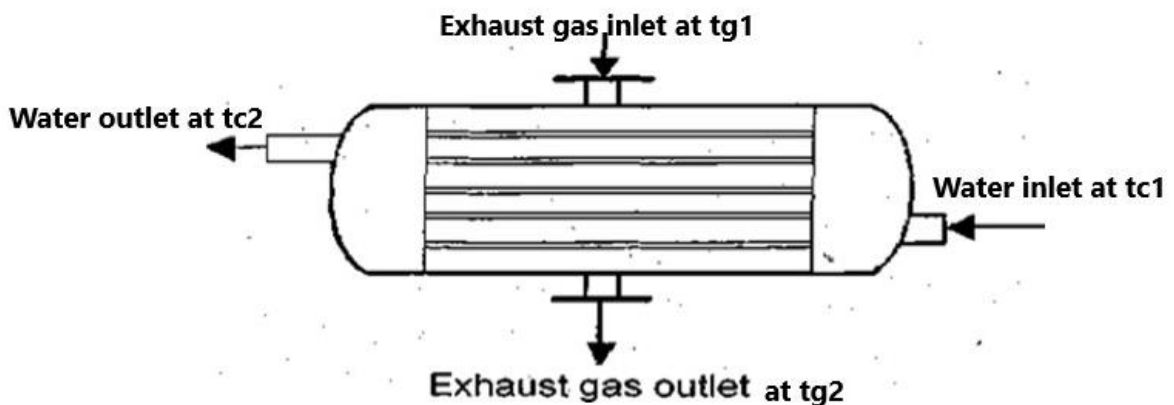


Figure 11.4 – Exhaust gas calorimeter

Writing the heat balance for calorimeter as, in the calorimeter

Heat rejected by the exhaust gases = Heat gained by the cooling water

$m_g \times C_{pg} \times (t_{g1} - t_{g2}) = m_{wc} \times C_{pw} \times (t_{c2} - t_{c1})$

So, $m_g \times C_{pg} = [m_c \times C_{pw} \times (t_{c2} - t_{c1})] / (t_{g1} - t_{g2})$

Now, the total heat carried away by the exhaust gases,

$H_g = m_g \times C_{pg} \times (t_g - t_r)$

$= \{ [m_{wc} \times C_{pw} \times (t_{c2} - t_{c1})] / (t_{g1} - t_{g2}) \} \times (t_g - t_r)$

$= \{ [\dots \times 4.187 \times (\dots - \dots)] / (\dots - \dots) \} \times (\dots - \dots)$

$H_G = \dots \dots \dots \text{kJ/min}$

D) Heat lost in friction (from Willan’s Line Method)

$H_{FP} = \dots \dots \dots \text{kJ / min.}$

E) Unaccounted Heat Loss (by difference) (Heat Lost due to radiation, pumping losses, errors of observation etc.)

$H_U = (\text{Heat supplied by combustion of fuel}) - [(\text{Heat equivalent of BP}) + (\text{Heat Carried away by Jacket cooling water}) + (\text{Heat carried away by exhaust Gases}) + (\text{Heat lost in friction})]$

$= H_F - [H_{BP} + H_W + H_G + H_{FP}]$

$= \dots \dots \dots$

$H_U = \dots \dots \dots \text{kJ / min}$

XII. Results

Heat balance sheet forN brake load

HEATCREDIT			HEATDEBIT		
Heat supplied	kJ/min	%	Heat Expenditure	kJ/min	%
Heat supplied by combustion of fuel (H _F)		100	A) Heat equivalent to BP (H _{BP})		
			B) Heat carried by jacket water (H _w)		
			C) Heat carried by exhaust gases (H _G)		
			D) Heat lost in friction (H _{FP})		
			E) Unaccounted heat loss (H _U)		
Total		100			100

XIII. Interpretation of Results

XIV. Conclusions and Recommendations

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Calculate BSFC of engine in kg/(kW-hr) preferably for full load.
2. Draw a graph of exhaust temperature with engine load based on the observations.
3. Draw a pie chart showing the heat expenditure or heat debit based on the calculations.
4. Justify “varying the cooling water flow rate influences the heat balance of an internal combustion engine.”
5. Explain the importance of including all forms of heat losses when preparing a heat balance sheet for an internal combustion engine.”

[Space for Answer]

XVI. References / Suggestions for Further Reading

- Performance and heat balance test on diesel engine https://www.youtube.com/watch?v=wr5JsovSX_o
- Factors reducing the performance of engine over time: <https://www.youtube.com/watch?v=uj8hjAjl7p4>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the Equipment and Measuring Instruments	20%
2	Noting the Observations	20%
3	Calculations of the parameters	20%
Product Related (10 Marks)		(40%)
4	Interpretation of the result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 12: Morse Test on I.C. engine test rig

I. Practical Significance

Friction existing in the parts of the engine leads to the power loss and so the reduced efficiency. Estimation of the engine's friction power accurately provides guidelines to optimize the engine performance, thereby increasing the brake thermal efficiency, reducing fuel consumption, and also reducing the exhaust pollution. A Morse Test is conducted on a multi-cylinder petrol/diesel engine to determine the indicated power developed in each cylinder without using the engine indicator device, and also the engine friction power. The test is comparatively simple to conduct and gives fairly accurate results.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer –
'Analyze engine performance based on its indicated power and friction power loss.'

III. Course Level Learning Outcome (CO)

CO3 - Carryout test for the performance of an I.C. engine.

IV. Laboratory Learning Outcome(s)

- Measure the speed & load by using tachometer & dynamometer.
- Determine indicated power and mechanical efficiency.

V. Relative Affective Domain-related Outcome(s)-

- Follow safety practices.
- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices Follow ethical Practices.

VI. Minimum Theoretical Background with diagram

Effect of engine speed on frictional power loss: In general, when the engine speed increases, the frictional power loss of the engine also increases due to the increased relative motion between the parts. For few parts, it is opposite. Moreover, the variation in the engine speed affects the engine temperature due to the variation in the number of firings per unit time, and also the change in the friction pattern of the parts. This variation in engine parts' temperature affects the relative expansion and contraction of the parts of different materials, and also it affects the lubricating properties of the lubricating oil. Usually, the oil loses its lubricating ability as the engine temperature rises. The overall effect of engine speed variation is to vary the amount of frictional power loss of the engine. This, in turn, will change the amount of useful power available at the engine crankshaft, which is the brake power. We can see that the Friction Mean Effective Pressure (FMEP) increases with the engine speed as shown in Fig. 12.1. FMEP is the portion of the indicated mean effective pressure (IMEP) that is lost due to internal friction within an engine. FMEP doesn't contribute to useful engine power. It

represents the pressure required to overcome friction between moving parts like pistons, connecting rods, and cylinder walls, including the pumping losses.

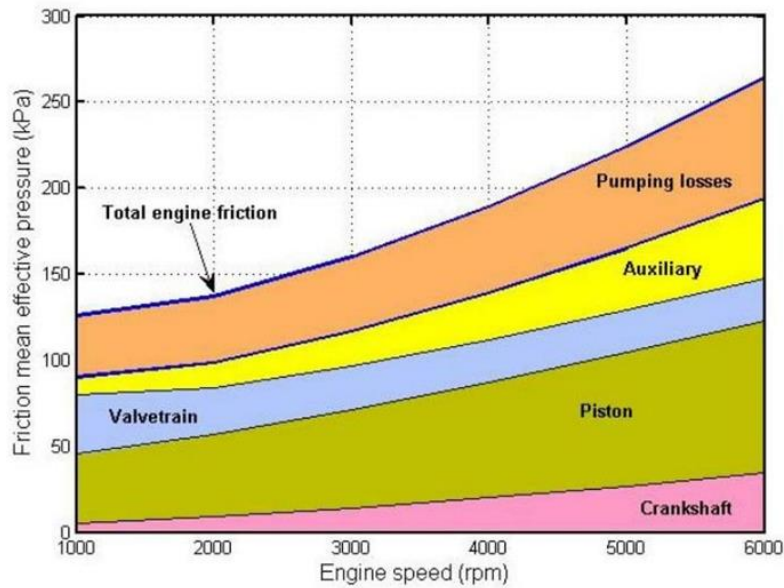


Figure 12.1 – Variation of engine friction with engine speed

VII. Experimental setup

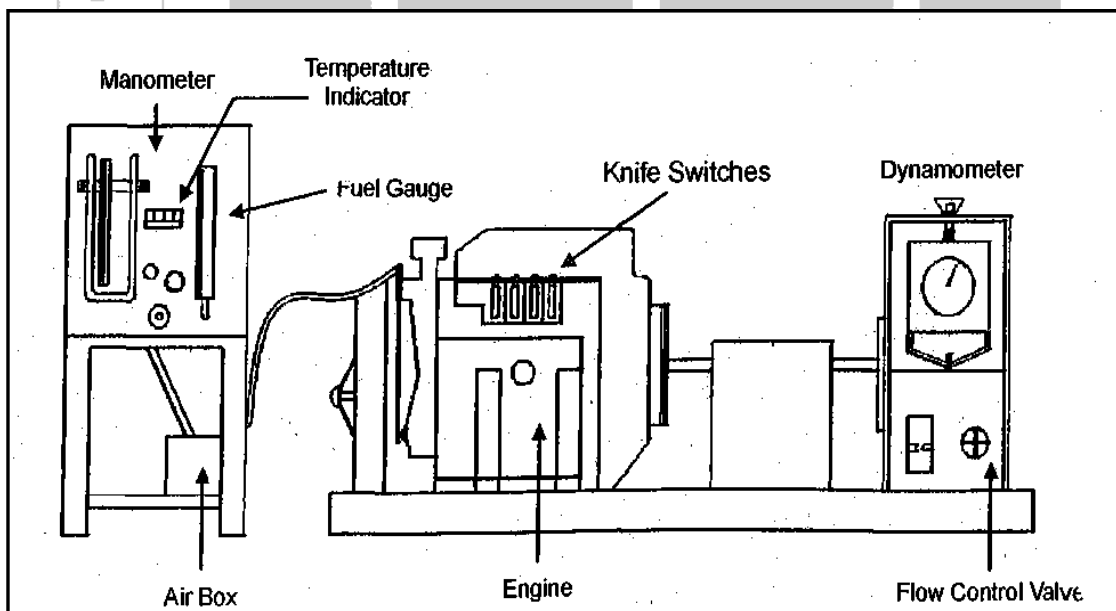


Figure 12.2 Four-stroke four-cylinder petrol engine test rig with hydraulic dynamometer



Figure 12.3 Four-stroke Four-cylinder Petrol engine Morse Test rig

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Engine	Type – multi-cylinder (3 or 4) Four Stroke Petrol / Diesel Engine, Bore - 80 mm, Stroke –110 mm, Power developed-3.75KW	1
2	Dynamometer (any one type)	Hydraulic Dynamometer with constant, $K = 2000$	1
		Eddy current Dynamometer with constant, $K = 200$	
3	Tachometer	Speed range 0 to 5000 rpm	1

IX. Precautions to be Followed

1. Check diesel, oil, and coolant levels before starting the engine.
2. Ensure proper connections of the battery and high-tension distributor to spark plug cables.
3. Don't tamper with ignition timing, distributor, governor, and fuel injector settings.
4. Stay safely away from moving/rotating components.
5. Never stop the engine in load and never use the decompression lever to stop it.

X. Procedure

1. Start the water supply of the engine and dynamometer.
2. Remove air bubbles in the fuel pipe and adjust the dynamometer load to zero, if applicable.
3. Start the engine and run it at no load for about 15 minutes to warm up.

4. Apply a suitable amount of load on the engine with the help of a dynamometer such that the engine attains around half the speed that of its maximum speed. This speed, called ‘Test Speed’, is to be attained in all further observations. Note the dynamometer load (i.e., when all the cylinders are firing).
5. Cut off the first cylinder by short-circuiting the spark plug for S.I. engines (or stopping the fuel supply for C.I. engines). This causes a drop in engine speed below the Test Speed. Reduce and adjust the dynamometer load to restore the Test Speed. Note the dynamometer load (i.e., when the first cylinder is cut off).
6. Fire the first cut-off cylinder and then cut off the second cylinder. Reduce and adjust the dynamometer load to restore the Test Speed. Note the dynamometer load (i.e., when the second cylinder is cut off).
7. Repeat this procedure by sequentially cutting off the third and fourth cylinders, and note down the respective dynamometer load.
8. Run the engine for about 15 minutes at no load and then shut it down.
9. Perform the calculations for Indicated Power, Frictional Power, and Mechanical Efficiency.

XI. Observations and calculations

Test Speed of the engine, $N = \dots\dots\dots$ rpm, will be constant for all sets of readings.

Observations Table

Sr. No.	Particulars when n^{th} Cylinder is cut off	Nil	First	Second	Third	Fourth
1	Load(F)kg	F =	$F_1 =$	$F_2 =$	$F_3 =$	$F_4 =$
2	Load in N ($F \times 9.81$)	W =	$W_1 =$	$W_2 =$	$W_3 =$	$W_4 =$

Calculation Table for Brake Power

1	Brake Power of the engine when all the cylinders are firing	$P_B = (W \times N) / K$ = ----- = -----kW.
2	Brake Power of the engine when the first cylinder is cut off	$P_{B1} = (W \times N) / K$ = ----- = -----kW.

a) Calculations for indicated power:

Indicated power of the first cylinder,

$$P_{I1} = P_B - P_{B1} = \dots\dots\dots = \dots\dots\dots \text{ kW}$$

Indicated power of the second cylinder,

$$P_{I2} = P_B - P_{B2} = \dots\dots\dots = \dots\dots\dots \text{ kW}$$

Indicated power of the third cylinder

$$P_{I3} = P_B - P_{B3} = \dots\dots\dots = \dots\dots\dots \text{ kW}$$

Indicated power of the fourth cylinder

$$P_{I4} = P_B - P_{B4} = \dots\dots\dots = \dots\dots\dots \text{ kW}$$

So, the indicated power of all the cylinders or engine,

$$\begin{aligned} P_I &= P_{I1} + P_{I2} + P_{I3} + P_{I4} \\ &= \dots\dots\dots + \dots\dots\dots + \dots\dots\dots + \dots\dots\dots \\ &= \dots\dots\dots \text{ kW.} \end{aligned}$$

b) Calculations for friction power:

$$P_F = P_I - P_B = \dots\dots\dots = \dots\dots\dots \text{ kW}$$

c) Calculations for mechanical efficiency:

Mechanical efficiency of the engine,

$$\begin{aligned} \eta_{\text{mech}} &= (P_B/P_I) \times 100 \\ &= (\dots\dots\dots / \dots\dots\dots) \times 100 \\ &= \dots\dots\dots \% \end{aligned}$$

XII. Results

1. Brake power, $P_B = \dots\dots\dots$ kW.
2. Indicated power, $P_I = \dots\dots\dots$ kW.
3. Friction power, $P_F = \dots\dots\dots$ kW.
4. Mechanical efficiency, $\eta_{mech} = \dots\dots\dots$ %.

XIII. Interpretation of Results

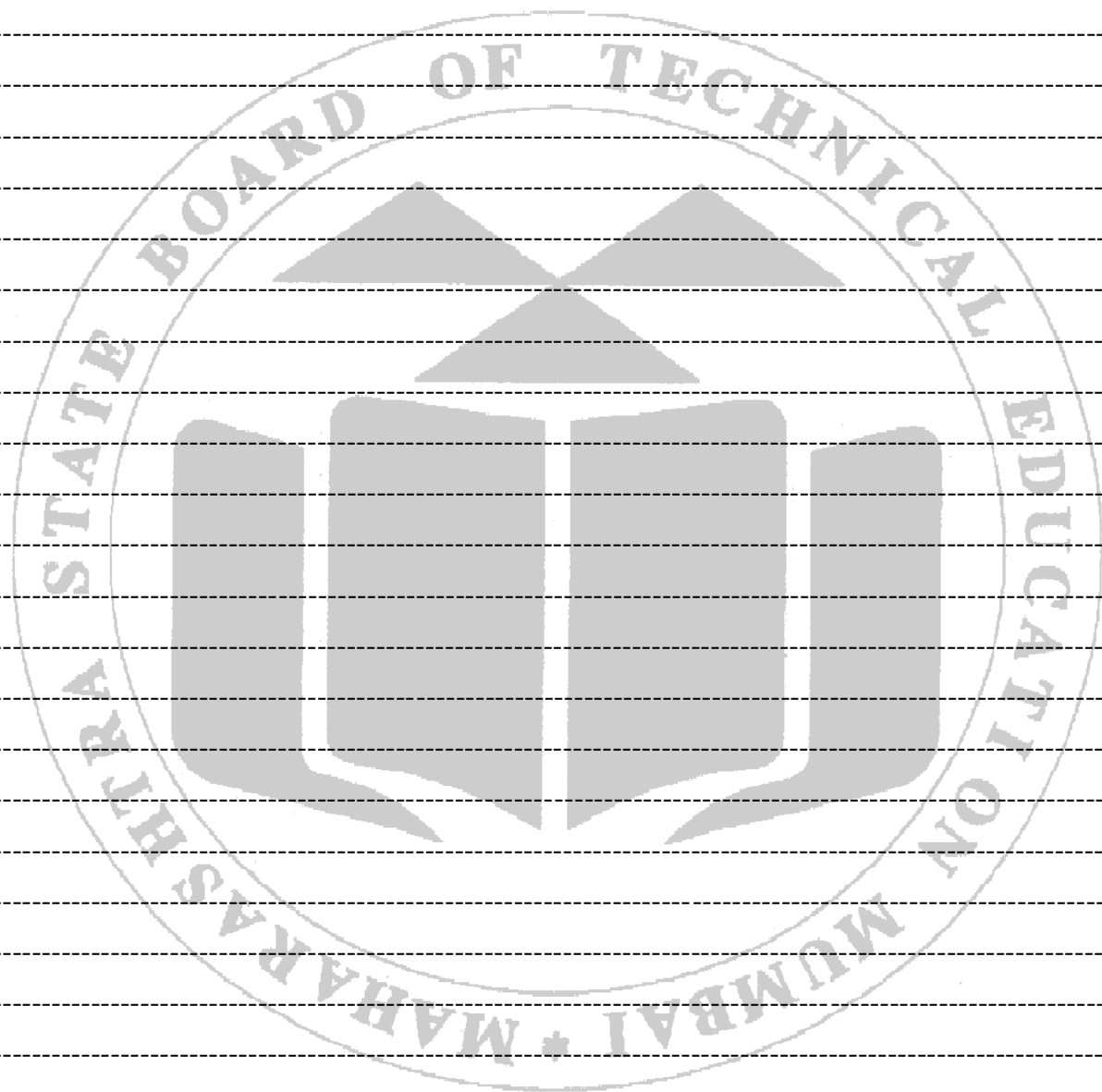
XIV. Conclusions and Recommendations

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Calculate the average indicated mean effective pressure of the engine if the dimensions of the cylinders are known.
2. State the limitations of the Morse Test.
3. State the factors inducing error in the results of the Morse Test.
4. State the type of engine typically used for the Morse test.
5. List and explain the key precautions that must be taken when performing a Morse test on an IC engine.

[Space for Answer]



XVI. References / Suggestions for Further Reading

- Procedure of Morse Test:<https://www.youtube.com/watch?v=AJOTtt2D3WQ>
- Importance of firing order of engine:<https://www.youtube.com/watch?v=ss0GMKBYCks>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the Equipment and Measuring Instruments	20%
2	Noting the Observations	20%
3	Calculations of the parameters	20%
Product Related (10 Marks)		(40%)
4	Interpretation of the result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 13: Use of exhaust gas analyzer for S.I. engine

I. Practical Significance

An exhaust gas analyzer is an essential diagnostic and monitoring tool used to evaluate the combustion efficiency and emission levels of petrol (gasoline) engines. Its practical significance includes:

- Emission Monitoring and Compliance
- Estimation of Engine Combustion Efficiency
- Optimization of Air-Fuel Ratio
- Maintenance and Troubleshooting of the engine

Using an exhaust gas analyzer for petrol engines is practically significant for ensuring environmental compliance, engine efficiency, and operational safety. It is an indispensable tool in both workshop diagnostics and engineering research.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer-
'Assess performance of the S.I. engine using exhaust gas analyzer.'

III. Course Level Learning Outcome (s)

CO3 – Carryout a test for the performance of an I.C. engine.

IV. Laboratory Learning Outcome(s)

- Measure various pollutants in the S.I. engine.
- Analyze pollutants in the given S.I. engine.

V. Relative Affective Domain-related Outcome(s)

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background

PUC Test:

PUC Test means 'Pollution Under Control' Test. This test is conducted on the vehicle to be tested at the Government (RTO) authorized PUC Center. Now, this test is computerized, in which the Exhaust Gas Analyzer is connected to a computer and the computer is connected to the 'Parivahan' web portal of the Government. Once connected, all the data of vehicle registration and the data of emission standards that the vehicle must comply with are available for the Test.

Purpose of PUC Test –

It is carried out to ensure vehicles comply with emission standards set by the government, thereby reducing vehicular pollution and its impact on public health and the environment. The test measures the amount of pollutants and other elements present in the vehicle exhaust. The

vehicle has to have a valid PUC certificate, which is valid for 6 months. It means the vehicles need to be tested every six months. If the vehicle does not comply with the emission standards, then necessary maintenance work has to be carried out for its compliance.

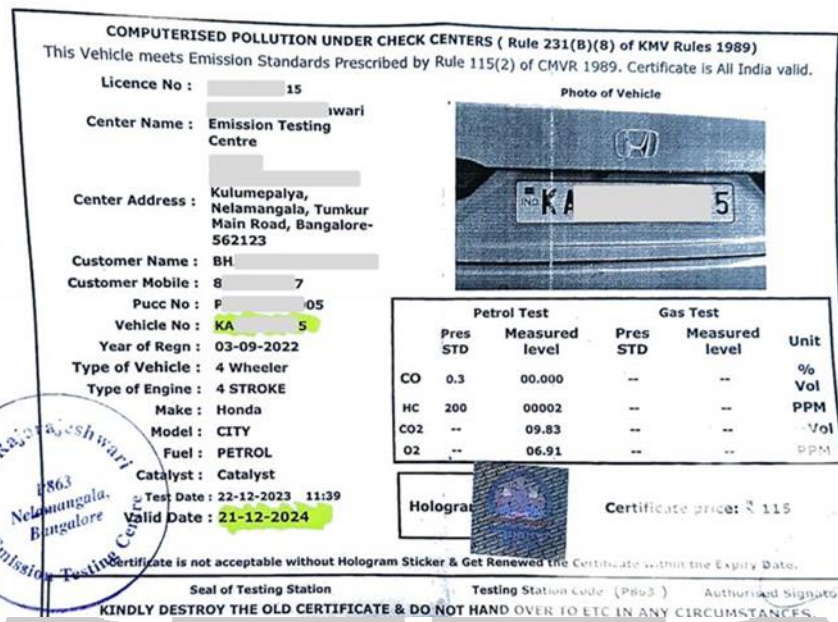


Figure 13.1: PUC Certificate

Bharat Stage Emission Standards in India:

BS6 Emission Norms for Two & Three-wheeler:

Although the units of emission mentioned in the following table are g/km, the units on the analyzer are in % and ppm, as applicable. The PUC certificate is provided as per the units on the analyzer.

Vehicle Type	Pollutants	BS6 Limit	
		SI (petrol)	CI (diesel)
Two-Wheelers	Particulate Matter (PM)	0.0045	0.0045
	Nitrogen Oxide (NOx)	0.06	0.09
	Carbon Monoxide (CO)	1.0	0.50
	Hydrocarbons (HC)	0.10a	0.10
Three-Wheelers	Particulate Matter (PM)	-	0.025
	Nitrogen Oxide (NOx)	0.085	0.10
	Carbon Monoxide (CO)	0.44	0.22
	Hydrocarbons (HC)	0.35	0.10

Figure 13.2 – BS6 Norms for 2 and 3-Wheeler

BS6 Emission Norms for Four-wheeler light-duty vehicles:

Petrol Emission Norms

Norm	CO (g/km)	HC (g/km)	NOx (g/km)	HC + NOx (g/km)	PM (g/km)
BS IV	1	0.1	0.08	-	Not specified
BS VI	1	0.1	0.06 (25%↓)	-	0.005

Diesel Emission Norms

Norm	CO (g/km)	HC (g/km)	NOx (g/km)	HC + NOx (g/km)	PM (g/km)
BS IV	0.50	-	0.25	0.30	0.025
BS VI	0.50	-	0.08 (68%↓)	0.17 (43%↓)	0.0045 (82%↓)

Source: Economics times *For light Duty Vehicles

Figure 13.3 – BS6 Norms for 4-Wheeler

VII. Experimental setup



Figure 13.4 – Exhaust Gas Analyser

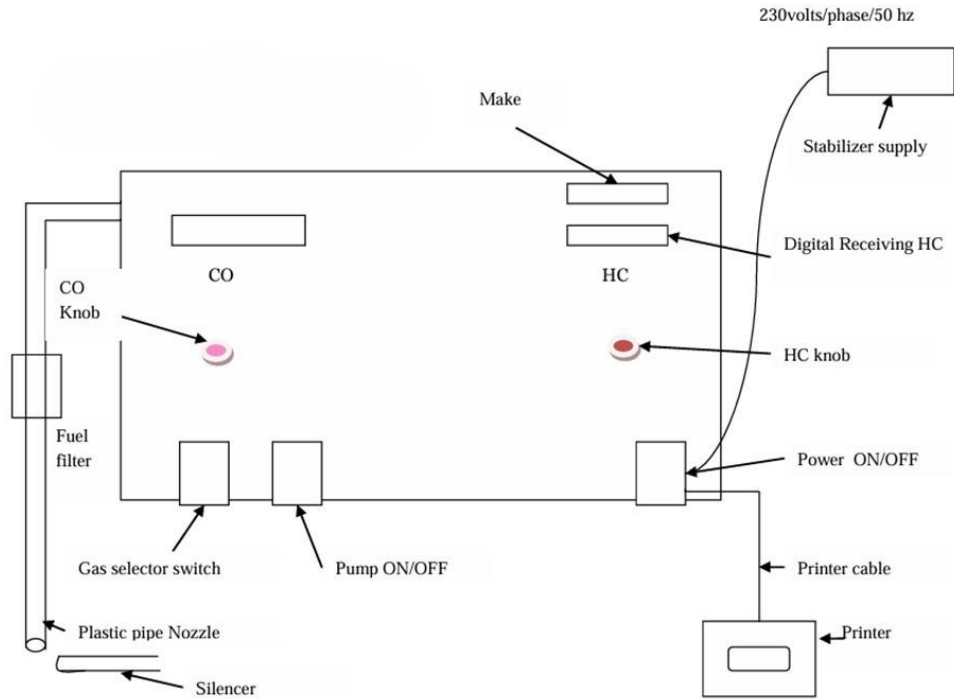


Figure 13.5 – Exhaust Gas Analyzer controls and connections

VIII. Required Resources/apparatus/equipment with specifications

Sr.No.	Name of Resource	Suggested Broad Specification	Quantity
1	Exhaust Gas Analyzer	CO (%) - Range 0-10	1
		HC (ppm) - Range 0-10000	
		CO ₂ (%) - Range 0-20	
		NO _x (ppm) - Range 0-5000	
		RPM - Range 0-9000	
2	Dwell-tachometer (RPM)	RPM - Range 0-10000	1
3	Vehicle to be tested	Available vehicle	1

(Note: These specifications are for reference only; actual specifications may vary)

IX. Precautions to be followed (Safety instructions / Rules / Standards)

- Ensure the handbrake is engaged and the vehicle is in neutral gear.
- Handle the Exhaust Gas Analyzer carefully.

X. Procedure

Note - Refer to the manufacturer’s catalogue of available analyzer for the procedure.

1. Connect the power supply cable and exhaust gas probe to the exhaust gas Analyzer.
2. Allow the analyzer to warm up for 15 minutes. Then, calibration is automatically carried out, and the analyzer is ready for measurement.
3. Start the engine and let it warm up at its idling speed.
4. Insert the exhaust gas probe/nozzle into the exhaust muffler. Wait for a few minutes.
5. Set the CO and HC value to zero by using the knob.
6. Switch on the pump. Operate the gas selector switch and set it to CO and HC mode.
7. Note the reading of CO, HC, CO₂, and O₂ and take a printout.
8. Take additional readings at cruising speed and higher speed by adjusting the accelerator.
9. Switch off the pump and remove the pipe from the exhaust muffler.

Note: For a car, during the test, measure the engine speed using a dwell-tachometer

XI. Observation and calculations

Observation Table

Sr. No.	Engine Speed (rpm)	CO (%)	HC (ppm)	CO ₂ (%)	O ₂ (%)
1	Idling =				
2	Cruising =				
3	High-power =				

XII. Result(s)

At idling speed of engine,

1. CO = %.
2. HC = ppm.
3. CO₂ = %
4. O₂ = %

XIII. Interpretation of results

XVI. References/Suggestions for further reading

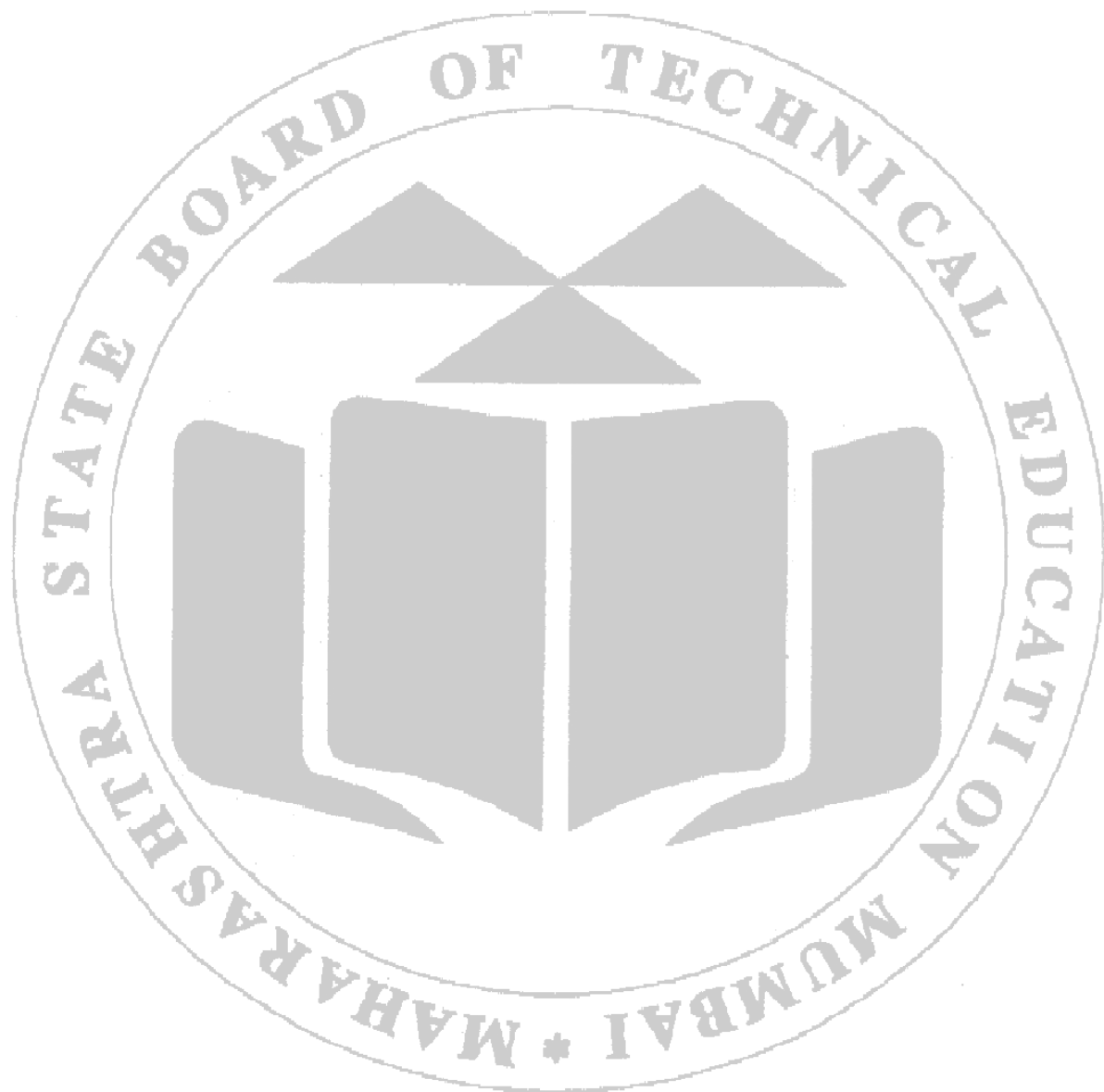
- Government online services regarding PUC: <https://puc.parivahan.gov.in/puc/>
- IndianEmissionsRegulations: https://www.araiindia.com/pdf/Indian_Emission_Regulation_Booklet.pdf

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the Equipment and Measuring Instruments	20%
2	Noting the Observations	20%
3	Calculations of the parameters	20%
Product Related (10 Marks)		(40%)
4	Interpretation of the result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Space to paste the PUC certificate obtained for the tested vehicle.



Practical No.14 Use of exhaust gas analyzer for C.I. engine

I. Practical Significance

An exhaust gas analyzer is an essential diagnostic and monitoring tool used to evaluate the combustion efficiency and emission levels of petrol (gasoline) engines. Its practical significance includes:

- Emission Monitoring and Compliance
- Estimation of Engine Combustion Efficiency
- Optimization of Air-Fuel Ratio
- Maintenance and Troubleshooting of engine

Using an exhaust gas analyzer for petrol engines is practically significant for ensuring environmental compliance, engine efficiency, and operational safety. It is an indispensable tool in both workshop diagnostics and engineering research.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer – ‘Assess performance of the C.I. engine using exhaust gas analyzer.’

III. Course Level Learning Outcome (CO)

CO3 - Carryout test for the performance of an I.C. engine.

IV. Laboratory Learning Outcome(s)

- Measure various pollutants in the C.I. engine.
- Analyze pollutants in the given C.I. engine.

V. Relative Affective Domain Related Outcome(s)

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Minimum Theoretical Background

Major Pollutants in Diesel Engine Exhaust and their effects:

Major pollutants in diesel engine exhaust are Carbon monoxide (CO), unburnt hydrocarbons (HC), Nitrogen oxides (NO_x), sulfur oxides (SO_x), Particulate Matter (PM), and carbon dioxide (CO₂).

Bharat Stage Emission Standards in India:

BS6 Emission Norms for diesel vehicles: Although the units of emission mentioned in the following table are g/km, the units on the analyzer are in % and ppm, as applicable. The PUC certificate is provided as per the units on the analyzer.

Diesel Emission Norms

Norm	CO (g/km)	HC (g/km)	NO _x (g/km)	HC + NO _x (g/km)	PM (g/km)
BS IV	0.50	-	0.25	0.30	0.025
BS VI	0.50	-	0.08 (68%↓)	0.17 (43%↓)	0.0045 (82%↓)

Source: Economics times *For light Duty Vehicles

Figure 14.1 – BS6 Norms for diesel vehicles

PUC certificate for a diesel vehicle:

Form 59
[See rules 115 (2)]

Pollution Under Control Certificate																																						
Authorised By : Government of Uttar Pradesh																																						
Date : 07/05/2023 Time : 13:12:23 PM Validity upto : 06/11/2023																																						
Certificate SL. No. : UP03400210003201 Registration No. : UP34T1714 Date of Registration : 03/Jan/2011 Month & Year of Manufacturing : -2010 Valid Mobile Number : *****0000 Emission Norms : Bharat (Trem) Stage III A Fuel : DIESEL PUC Code : UP0340021 GSTIN : Fees : Rs.105.00 (GST to be paid extra as applicable) MIL observation : No																																						
Vehicle Photo with Registration plate 60 mm x 30 mm																																						
<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th style="width: 10%;">Sr. No.</th> <th style="width: 30%;">Pollutant (as applicable)</th> <th style="width: 15%;">Units (as applicable)</th> <th style="width: 15%;">Emission limits</th> <th style="width: 30%;">Measured Value (upto 2 decimal places)</th> </tr> <tr> <th>1</th> <th>2</th> <th>3</th> <th>4</th> <th>5</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Idling Emissions</td> <td>Carbon Monoxide (CO)</td> <td>percentage (%)</td> <td></td> <td></td> </tr> <tr> <td>Hydrocarbon, (THC/HC)</td> <td>ppm</td> <td></td> <td></td> </tr> <tr> <td rowspan="3">High idling emissions</td> <td>CO</td> <td>percentage (%)</td> <td></td> <td></td> </tr> <tr> <td>RPM</td> <td>RPM</td> <td>2500 ± 200</td> <td></td> </tr> <tr> <td>Lambda</td> <td>-</td> <td>1 ± 0.03</td> <td></td> </tr> <tr> <td>Smoke Density</td> <td>Light absorption coefficient</td> <td>1/metre</td> <td>2.45</td> <td>0.54</td> </tr> </tbody> </table> <p style="text-align: center; font-size: small;">This PUC certificate is system generated through the national register of motor vehicles and does not require any signature.</p>		Sr. No.	Pollutant (as applicable)	Units (as applicable)	Emission limits	Measured Value (upto 2 decimal places)	1	2	3	4	5	Idling Emissions	Carbon Monoxide (CO)	percentage (%)			Hydrocarbon, (THC/HC)	ppm			High idling emissions	CO	percentage (%)			RPM	RPM	2500 ± 200		Lambda	-	1 ± 0.03		Smoke Density	Light absorption coefficient	1/metre	2.45	0.54
Sr. No.	Pollutant (as applicable)	Units (as applicable)	Emission limits	Measured Value (upto 2 decimal places)																																		
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Idling Emissions	Carbon Monoxide (CO)	percentage (%)																																				
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	Lambda	-	1 ± 0.03																																			
Smoke Density	Light absorption coefficient	1/metre	2.45	0.54																																		
Note : 1. Vehicle owners to link their mobile numbers to registered vehicle by logging to https://puc.parivahan.gov.in																																						
Authorised Signature with stamp of PUC operator 60mm x 20 mm																																						

Figure 14.2 – PUC Certificate

VII. Experimental setup



Figure 14.3 – Exhaust Gas Analyzer

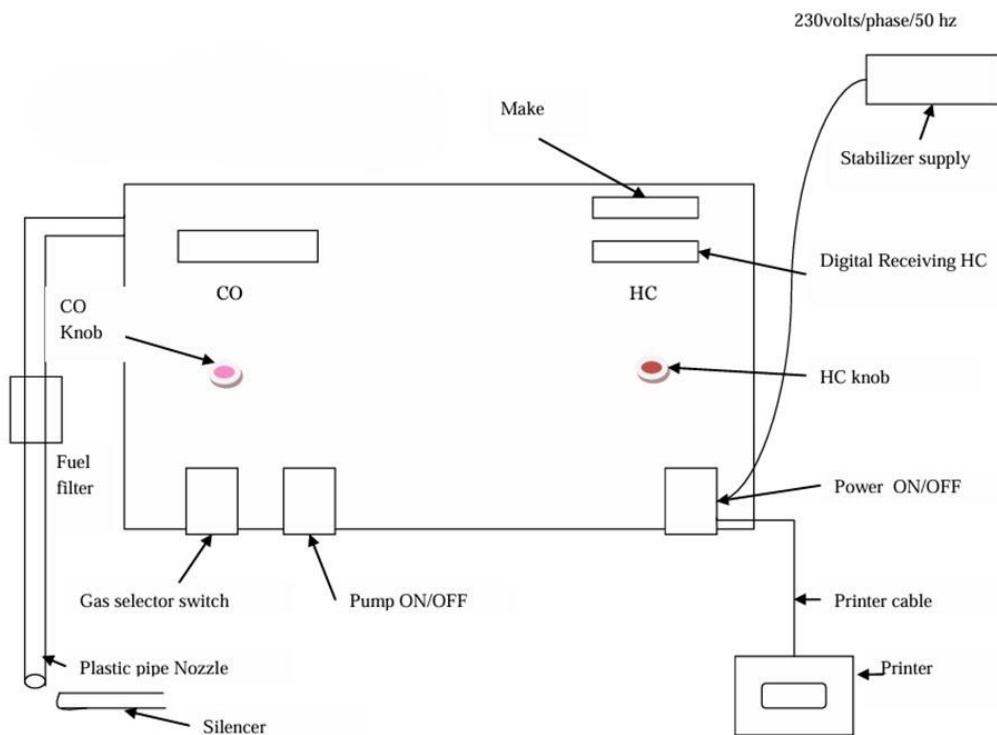


Figure 14.4 – Exhaust Gas Analyzer controls and connections

VIII. Required Resources /Apparatus/Equipment with specifications

Sr.No.	NameofResource	SuggestedBroadSpecification	Quantity
1	Exhaust Gas Analyzer	CO (%) - Range0-10	1
		HC (ppm) -Range0-10000	
		CO ₂ (%) - Range0-20	
		NO _x (ppm) -Range0-5000	
		SO _x (ppm) -Range0-2000 (optional)	
		Lambda (γ) -Range0.5-3 (optional)	
		RPM-Range0-9000	
2	Dwell-Tachometer (RPM)	RPM-Range0-10000	1
3	Vehicle to be tested	Available vehicle	1
4	Smoke Meter (optional)	Smoke Capacity (%) -Range0-100	1

IX. Precautions to be Followed

- Ensure the handbrake is engaged and the vehicle is in neutral gear.
- Handle the Exhaust Gas Analyzer carefully

X. Procedure

Note - Refer to the manufacturer's catalogue of available Analyzer for the procedure.

1. Connect the power supply cable and exhaust gas probe to the exhaust gas Analyzer.
2. Allow the analyzer to warm up for 15 minutes. Then, calibration is automatically carried out, and the analyzer is ready for measurement.
3. Start the engine and let it warm up at its idling speed.
4. Insert the exhaust gas probe/nozzle into the exhaust muffler. Wait for a few minutes.
5. Set CO, HC, and NO_x value to zero by using the knob, as applicable on the analyzer.
6. Switch on the pump. Operate the gas selector switch and set it to CO and HC mode.
7. Note the reading of CO, HC, NO_x, CO₂, O₂, λ , whichever is available, and take a printout.
8. Take additional readings at cruising speed and higher speed by adjusting the accelerator.
9. Switch off the pump and remove the pipe from the exhaust muffler.

Note: For the car, during the test, measure the engine speed by using a dwell-tachometer.

XI. Observations and calculations**Observation Table**

Sr. No.	Engine Speed (rpm)	CO (%)	HC (ppm)	NO _x (ppm)	CO ₂ (%)	O ₂ (%)	λ
1	Idling=						

Sr. No.	Engine Speed (rpm)	CO (%)	HC (ppm)	NO _x (ppm)	CO ₂ (%)	O ₂ (%)	λ
2	Cruising=						
3	High-power=						

XII. Results

At idling speed of engine,

- | | |
|---------------------------------|------------------------------|
| 1. CO = %. | 4. CO ₂ = % |
| 2. HC = ppm. | 5. O ₂ = % |
| 3. NO _x = ppm. | 6. λ = |

XIII. Interpretation of Results

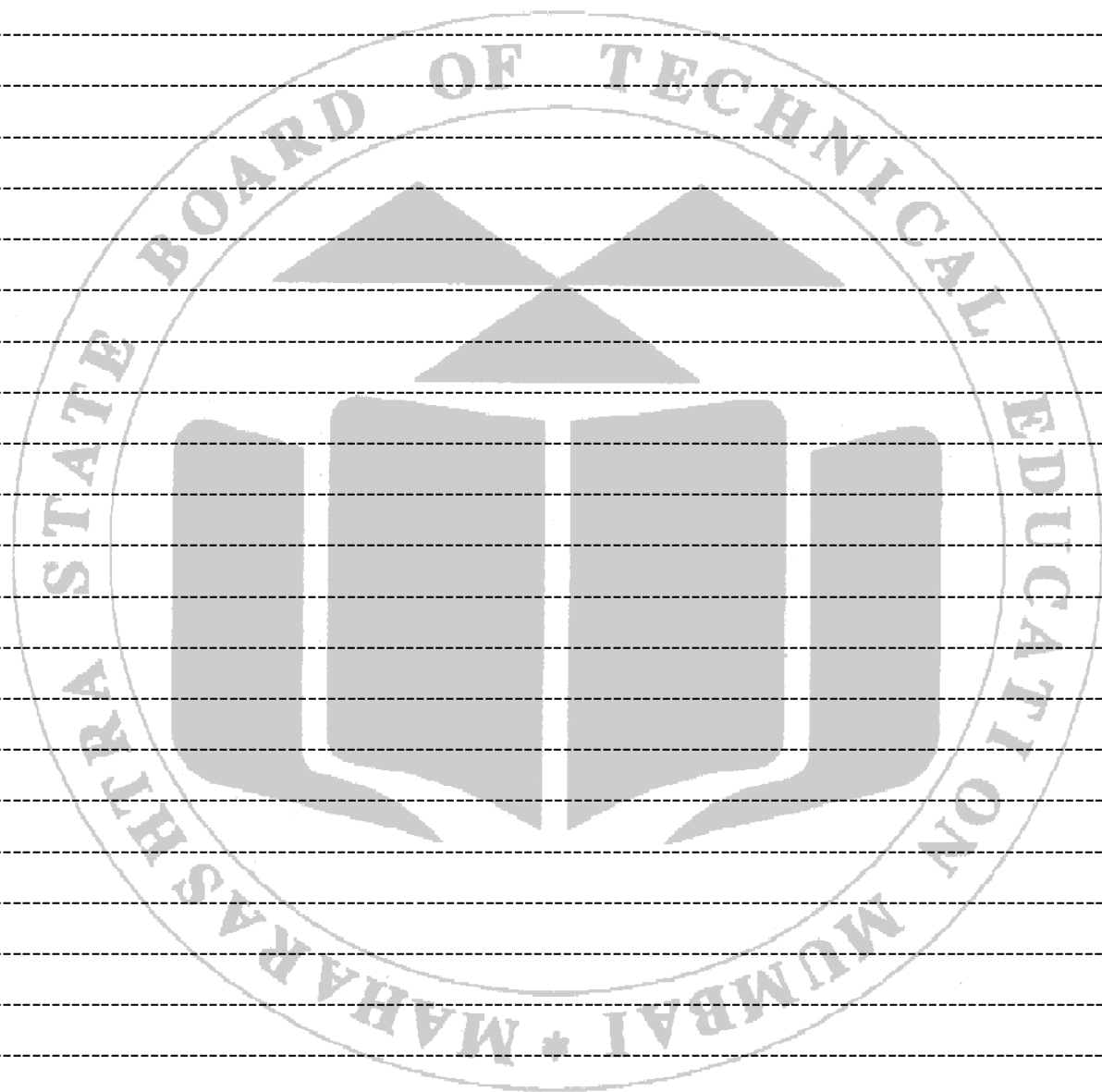
XIV. Conclusions and Recommendations

XV. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Draw a graph of NO_x (ppm) with the engine speed based on the observations.
2. Write down the specifications of the exhaust gas analyzer used by you, mentioning the range of the values.
3. If available, conduct a smoke opacity test using a smoke meter and write down its value.
4. Explain the essential steps you must take to properly prepare both the engine and the exhaust gas analyzer before starting measurements.
5. Describe how the air-fuel ratio in a spark-ignition engine influences the readings obtained from an exhaust gas analyzer

[Space for Answer]



XVI. References / Suggestions for Further Reading

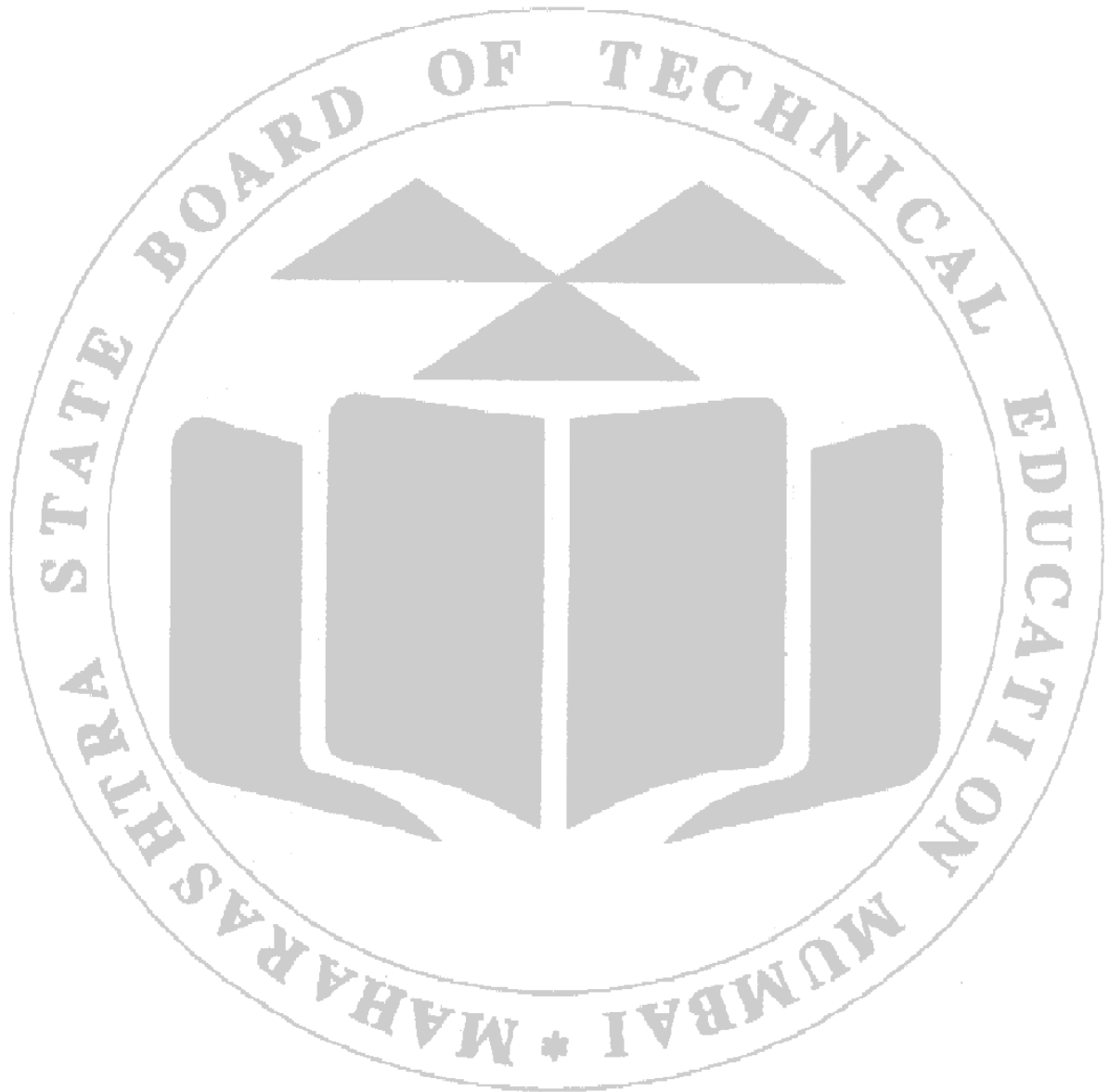
- BS7 emissions threaten diesel cars in India:
https://www.youtube.com/watch?v=3taBcd3Bg_Q
- Dimethyl ether as an alternative fuel for diesel engines:
<https://indiascience.dst.gov.in/videos/dimethyl-ether-as-fuel-e>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the measuring Instruments	20%
2	Noting the Observations	20%
3	Calculations of the parameters	20%
Product Related (10 Marks)		(40%)
4	Interpretation of the result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Space to paste the PUC certificate obtained for the tested vehicle.



Practical No. 15: Diagnosis test on I.C. engine using engine control unit

I. Practical Significance

Performing a diagnostic test on an IC engine using an engine scanner is practically significant as it enables early detection of faults, accurate troubleshooting, and efficient maintenance by identifying issues such as sensor failures, misfires, or fuel system problems. This process saves time and reduces repair costs by preventing unnecessary part replacements and labor. Additionally, it helps optimize engine performance, improves fuel efficiency, ensures compliance with emission standards, and supports preventive maintenance by monitoring engine health. With modern engines relying heavily on electronic control systems, engine scanners are essential tools for accessing real-time data, reading error codes, and ensuring the overall reliability and longevity of the engine.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer-
 ‘Assess condition and performance of the I.C. engine using diagnostic tools.’

III. Course Level Learning Outcome (s)

CO3 – Carry out test for the performance of an I.C. engine.

IV. Laboratory Learning Outcome(s)

- Interpret the notation code on the dashboard and monitor of the computer
- Diagnose the faults in the given I.C. engine.
- Suggest the remedies over the faults detected.

V. Relative Affective Domain-related Outcome(s)

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.
- Follow safety practices.

VI. Relevant Theoretical Background

Electronic Control Unit (ECU):

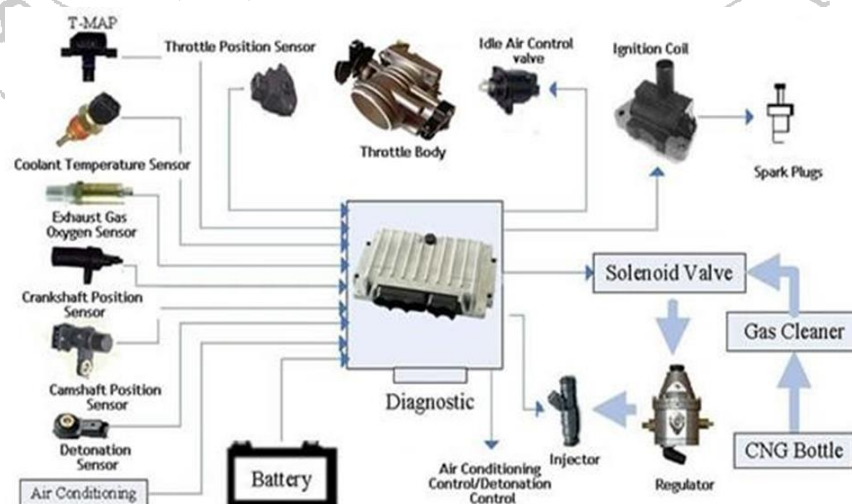


Figure 15.1 – ECU and connected components

It is also called an Engine Control Unit (ECU) or Electronic or Engine Control Module (ECM). It is a computer that performs functions pertaining to the vehicle engine operation and performance. It receives input data from sensors installed at various locations of the engine and also on the vehicle. It then processes that data, assesses the engine operating condition and finally makes real-time adjustments via the actuators to optimize the engine performance for improved torque-speed output, reduce fuel consumption, and emissions.

Location of ECU port for OBD II Scanner connection:

The ECU port for the connection of the data/power cable of the OBD II Scanner is located under the steering wheel usually near the clutch or brake pedal. See the white color port in figure 15.2. Its typical design ensures the correct fitment of the OBD II Scanner.



Figure 15.2 – Location of ECU port for OBD II Scanner connection

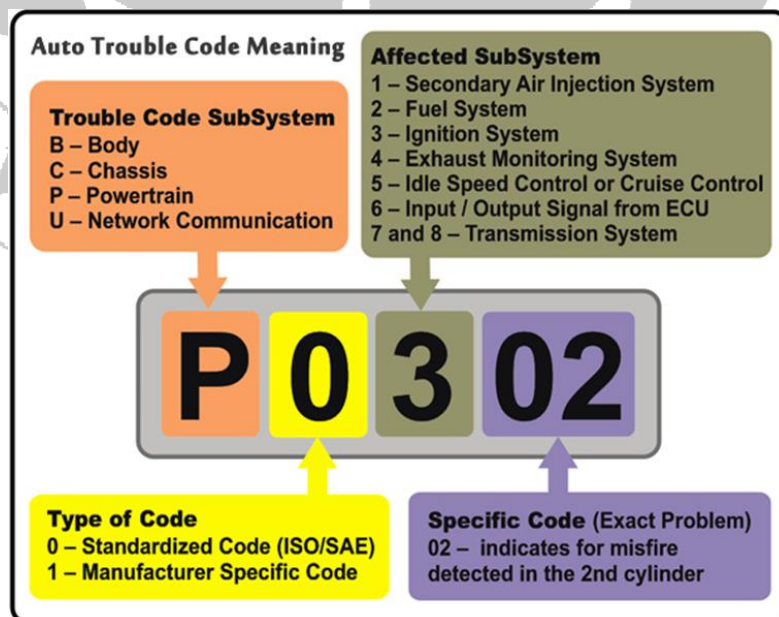


Figure 15.3 – OBD-II Diagnostic Fault Code designation

OBD fault codes: Following are a few examples of the fault codes with their description. The Students should refer the fault codes of the particular vehicle.

Powertrain Codes

- P0300 – Random/Multiple Cylinder Misfire Detected
- P0420 – Catalyist System Efficiency Below Threshold
- P0171 – System Too Lean (Bank 1)
- P0128 – Coolant Temperature below Thermostat Regulating Temperature
- P0442 – Evaporative Emission Control System Leak Detected (Small Leak)

Chassis Codes

- C0035 – Left Rear Wheel Speed Sensor Circuit
- C1214 – Brake Control Relay Contact Circuit Open
- C0036 – Right Front Wheel Speed Sensor Circuit
- C0561 – ABS Brake Control Module System
- C1210 – Brake Fluid Pressure Sensor Circuit

Body Codes

- B0020 – Front Passenger Side Deployment Loop Resistance High
- B1000 – Electronic Frontal Sensor Data
- B1200 – Climate Control Push Button Circuit Open
- B1325 – Oil Pressure Sensor Circuit
- B1422 – Seat Belt Pre-tensioner Deployment Control Circuit

Network Codes

- U0100 – Lost Communication with ECM/PCM A
- U0121 – Lost Communication with Anti-lock Brake System (ABS) Control Module
- U0073 – Control Module Communication Bus A Off
- U0140 – Lost Communication with Body Control Module
- U0401 – Invalid Data Received from Engine Control Module (ECM)

VII. Experimental setup



Figure 15.4 – OBD II Scanner and connectors

VIII. Required Resources/apparatus/equipment with specifications

Sr.No.	Name of Resource	Suggested Broad Specification	Quantity
1.	ECU	Available in the vehicle	1
2.	Sensors and Actuators	Available in the vehicle	1
3.	OBDII Car Diagnostic Tool	Grade II	1
4.	Visit to an authorized vehicle service station, e. g. TATA / Maruti / Hyundai, etc.	Field visit	1

IX. Precautions to be followed

- Use insulated tools and wear appropriate personal protective equipment (PPE).
- Ensure that engine parts are cooled down before touching them.
- Disconnect the battery to prevent electric shock or accidental short circuits.
- Refer Vehicle Manufacturer's Instruction Manual to connect and later disconnect the engine scanner at the designated location to prevent damage to the scanner or vehicle ECU
- Ensure there are no fuel leaks before starting the engine to prevent fire hazards.

X. Procedure

1. Park the vehicle on a level surface in neutral gear, engaging the handbrake.
2. Turn off the engine and allow it to cool down.
3. Turn the power ON of the On-Board Diagnostics (OBD II) Scanner or Tool. Select or enter the information of the vehicle in the Scanner Menu.
4. See the location of the OBD-II port shown in the Scanner (or Manufacturer's Instruction Manual) and identify it on the Vehicle. Usually, it is located beneath the dashboard on the driver's side near the clutch pedal.
5. Plug the diagnostic scanner into the OBD-II port carefully and securely.
6. Turn the ignition key to the ON position (don't start the engine unless required by the scanner).
7. Make the scanner ON and allow it to establish communication with the vehicle's ECU.
8. Select the correct vehicle make, model, and year if required by the scanner.
9. Use the scanner menu to read or retrieve stored and pending trouble codes.
10. Note down any error codes along with their descriptions, if provided.
11. Navigate to the "Live Data" or similar option on the scanner to observe real-time data from various sensors (e.g., RPM, coolant temperature, O₂ sensor values).
12. Interpret the fault codes and data to assess the health of the engine systems.
13. Refer to the manufacturer's code charts or service manuals for accurate fault interpretation.
14. Complete the necessary repair work or analysis, and clear the codes using the scanner.
15. Restart the engine and check if the issues persist or the Check Engine Light reappears.
16. Turn off the ignition and safely unplug the scanner from the OBD-II port.
17. Record all retrieved codes, findings, and any corrective actions taken in a lab report or diagnostic sheet for further reference.

XI. Observation and calculations
Observation Table

Sr.No.	Fault code	Fault/trouble description	Remedies for fault/trouble
	Generic Fault		
1			
2			
3			
4			
5			
	Specific Fault		
1			
2			
3			
4			
5			

XII. Result(s)

XIII. Interpretation of results

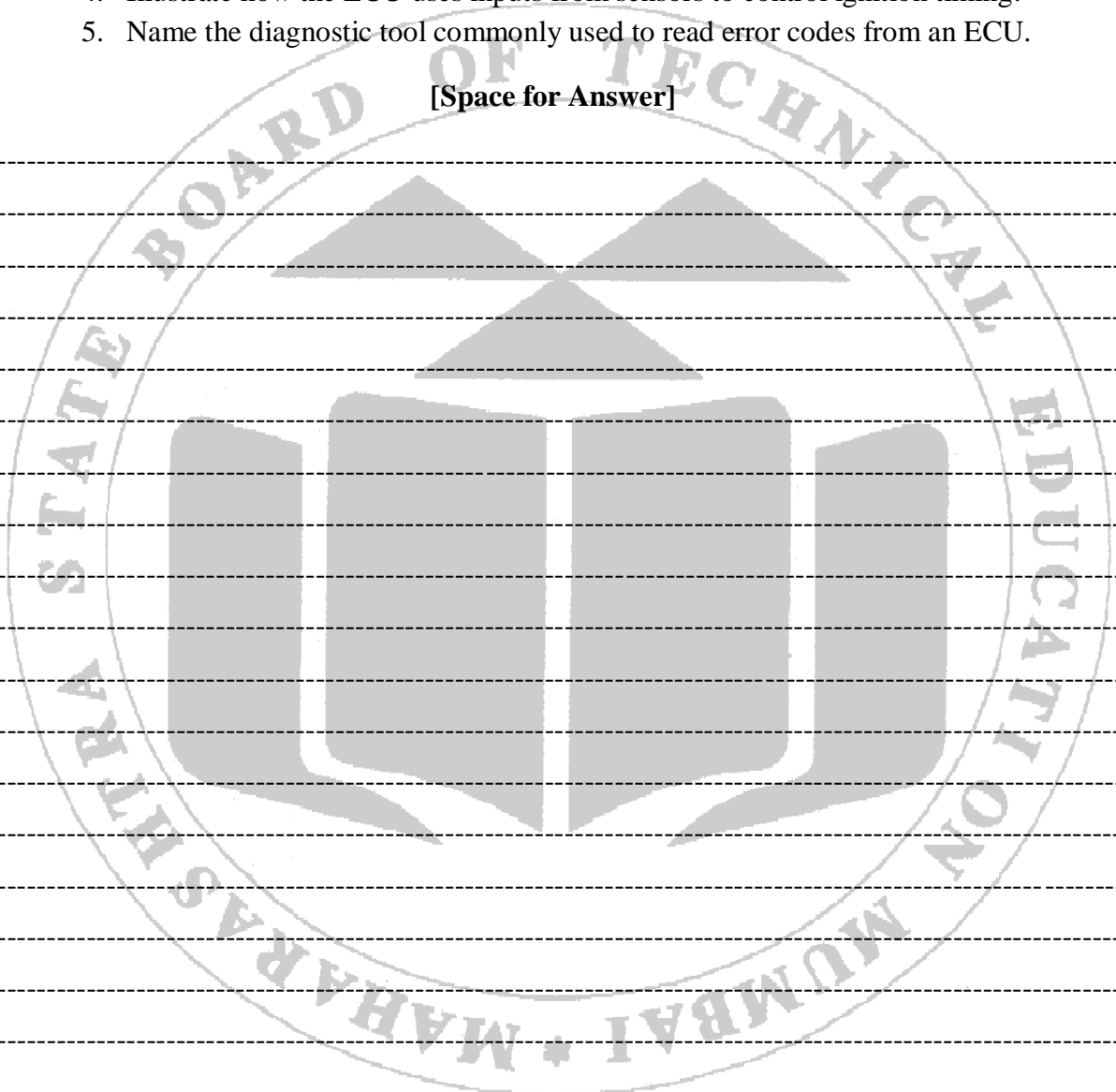
XIV. Conclusion and recommendation

XV. Practical-related questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. State the advantages of the OBD of a vehicle.
2. State the reason for recording the fault codes before clearing them from the ECU memory.
3. List any three manufacturers of the vehicle OBD Scanner along with the model number.
4. Illustrate how the ECU uses inputs from sensors to control ignition timing.
5. Name the diagnostic tool commonly used to read error codes from an ECU.

[Space for Answer]



A large, faint watermark of the Maharashtra State Board of Technical Education logo is centered on the page. The logo is circular and contains a stylized book and a mountain range. The text 'MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION' is written around the perimeter of the circle. Below the watermark, there are several horizontal dashed lines for writing the answer.

XVI. References/Suggestions for further reading

- OBD Codes: <https://www.obd-codes.com/>
- Use of OBD II Scanner: https://youtu.be/vgjoEqe_a5E

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Proper use of diagnostic tools	20%
2	Data interpretation skills	20%
3	Tool handling and safety	20%
Product Related (10 Marks)		(40%)
4	Interpretation of the result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 16: Test on two-stage reciprocating air compressor (Part I)

I. Practical Significance

Compressed air is essential for various applications, including inflating vehicle tires, spray painting, borehole operations, fettling tools in foundries, pneumatic clamps in machinery, cleaning in machine shops, food packaging, mining tools, and automotive service tools. As a result, the air compressor becomes a vital piece of equipment in most industries with nearly continuous operation. It draws in atmospheric air, compresses it, and supplies it to machines or equipment at the necessary pressure and airflow rate. A reciprocating air compressor can provide higher-pressure air, which increases with the number of compressor stages. Choosing the right compressor, capable of meeting application requirements mainly in terms of air pressure and flow rate, while consuming less energy, requires knowledge and skill to test performance parameters such as delivery pressure, capacity, drive power, and efficiency.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer: 'Select and maintain reciprocating air compressor for the desired industrial application.'

III. Course Level Learning Outcome (s)

CO4 - Analyze the performance of air compressor.

IV. Laboratory Learning Outcome(s)

- Perform the test using two stage reciprocating air compressor test rig to measure the various parameters like temperature, pressure, air flow rate, etc.
- Determine actual volume of free air delivered.

V. Relative Affective Domain-related Outcome(s)

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Relevant Theoretical Background

Working of a two-stage reciprocating air compressor:

Atmospheric air is compressed in the first stage or low-pressure (L.P.) cylinder from suction pressure P_1 to intermediate (or stage or intercooler) pressure P_2 , thereby increasing the temperature from T_1 to T_2 . This air is cooled down to temperature T_3 at constant pressure in the intercooler by an external cooling medium, air or water. The air is further compressed to the delivery pressure P_3 in the second stage or high-pressure (H.P.) cylinder, and air temperature increases to T_4 . This compressed air is then delivered to the air receiver.

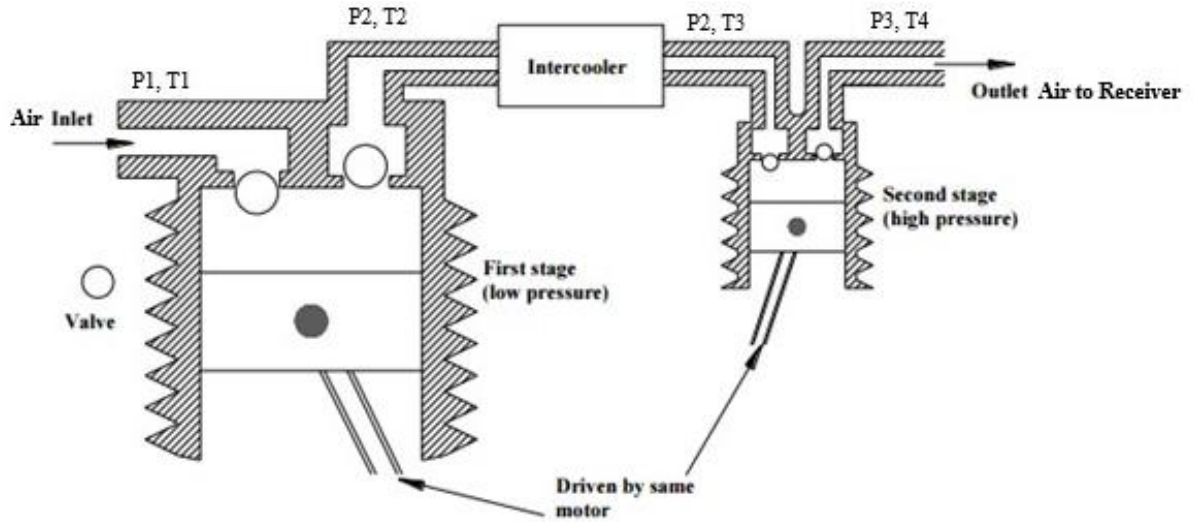


Figure 16.1 – Schematic diagram of two stage reciprocating air compressor

Terms related to air compressor:

- a) Suction pressure – Pressure of air at the inlet of the compressor.
- b) Discharge or delivery pressure – Pressure of the air at the outlet of the compressor.
- c) Pressure Ratio – It is the ratio of discharge pressure to the suction pressure of air.
- d) Free air delivery – It is the actual volume of air delivered by the compressor per unit time when reduced at normal pressure and temperature conditions.

VII. Experimental setup

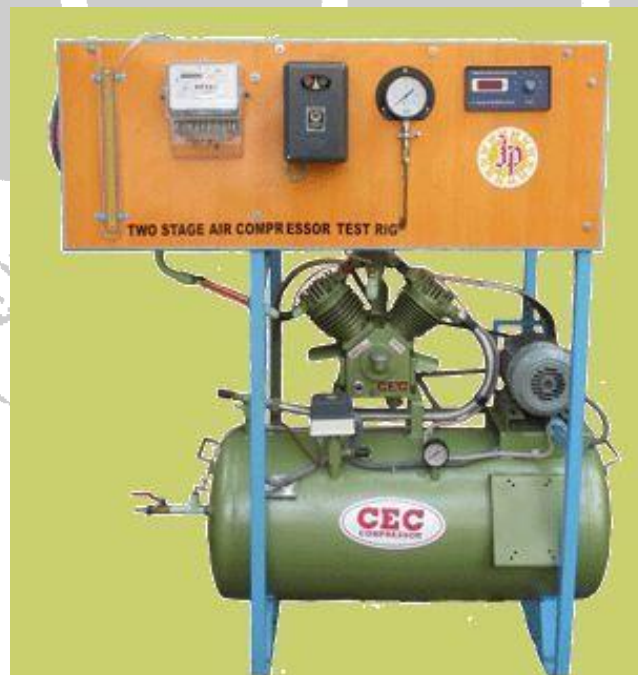


Figure 16.2 - Set up of two-stage reciprocating air compressor

VIII. Required Resources/apparatus/equipment with specifications

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Two-stage single-acting reciprocating air compressor with suitable motor drive	Speed 500 to 750 rpm. Delivery pressure of 7 to 10 kg/cm ² . Capacity about 200 to 300 LPM.	1
2	Pressure Gauge	Range -1 to 2 kg/cm ² for suction.	1
		Range 0 to 5 kg/cm ² for intercooler.	1
		Range 0 to 10 kg/cm ² for receiver.	1
3	Differential Manometer	U-tube water manometer	1
4	Air Box	About 50 liters of volume	1
5	Orifice plate	25 to 30 mm diameter fitted to air box	1
6	Thermometer	Mercury in glass or type K	4
	Thermocouple		
7	Digital temperature indicator	Pt100RTDsmV 4-20 A range (in case of thermocouple)	1
8	Tachometer	Speed range 0 to 1500 rpm	1

IX. Precautions to be followed

- Check and maintain the proper level of lubricating oil in the compressor crankcase.
- Stay away from the moving and hot parts of the compressor.

X. Procedure

1. Fill the manometer with water up to half level.
2. Keep the delivery valve and manometer cock on the suction line in closed position.
3. Start the compressor and open the manometer cock.
4. Let the air pressure build up in the air receiver.
5. Maintain the air pressure in the receiver constant by adjusting its air outlet valve. Note this delivery pressure reading shown by pressure gauge mounted on receiver.
6. Measure and note down the motor speed using a tachometer, keeping this delivery pressure constant.
7. Note down water manometer reading, suction pressure, intercooler pressure, delivery pressure, suction temperature, temperatures before and after intercooler, and delivery temperature, keeping the same delivery pressure constant.

XI. Observation and calculations**Observation:**

Diameter of orifice on air box (d) = mm = m.

Observation Table:

Sr. No.	Particulars	Notation	Unit	Reading value
1	Intake Pressure (gauge)	P_1 (gauge)	Kg/cm ²	
	Intake Pressure (absolute) P_1 (abs) = P(atm) + P_1 (gauge) = (.....) + (.....X 0.9806)	P_1	bar	
2	Intercooler pressure (gauge)	P_2 (gauge)	Kg/cm ²	
	Intermediate Pressure (absolute) P_2 (abs) = P(atm) + P_2 (gauge) = (.....) + (.....X 0.9806)	P_2	bar	
3	Delivery pressure (gauge)	P_3 (gauge)	Kg/cm ²	
	Delivery pressure (absolute) P_3 (abs) = P(atm) + P_3 (gauge) = (.....) + (.....X 0.9806)	P_3	bar	
4	Intake temperature	t_1	°C	
		$T_1 = t_1 + 273$	°K	
5	Temperature before intercooler	t_1	°C	
		$T_1 = t_1 + 273$	°K	
6	Temperature after intercooler	t_1	°C	
		$T_1 = t_1 + 273$	°K	
7	Delivery temperature	t_1	°C	
		$T_1 = t_1 + 273$	°K	
8	Motor Speed	N_1	rpm	
9	Manometer reading	h_1	mm	
		h_2	mm	

Calculations:

1. Density of air

Using the characteristic gas equation,

$$P_1 \times V_1 = m_a \times R_a \times T_1.$$

Where, m_a = mass of air

$$R_a = \text{Characteristic gas constant} = 287 \text{ J/kg}$$

Now, $m_a = P_1 \times V_1 / (R_a \times T_1)$

So, density of air,

$\rho_a = m_a / V_1 = P_1 / [R_a \times T_1]$, where P_1 is in N/m^2 .

$= P_1 / [R_a \times (t_1 + 273)]$

$= \dots\dots\dots / [287 \times (\dots\dots + 273)]$

$\rho_a = \dots\dots\dots \text{ kg/m}^3$

2. Water manometric head

$h_w = h_1 - h_2$

$= \dots\dots\dots$

$h_w = \dots\dots\dots \text{ mm of water}$

$= \dots\dots\dots \text{ m of water}$

3. Air head, causing the flow of air

$h_a = h_w \times \rho_w / \rho_a$

Where, $\rho_w = \text{Density of water} = 1000 \text{ kg/m}^3$

$h_a = (\dots\dots\dots \times 1000) / (\dots\dots\dots)$

$= \dots\dots\dots \text{ m of air}$

4. Actual volume of free air delivered

Area of Orifice, $a = (\pi/4) d^2 = (\pi/4) \times (\dots\dots\dots)^2 = \dots\dots\dots \text{ m}^2$

Actual volume of free air delivered,

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

$V_a = \dots\dots\dots \times \dots\dots\dots \times \sqrt{(2 \times 9.81 \times \dots\dots\dots)} \text{ m}^3/\text{s}$

$V_a = \dots\dots\dots \text{ m}^3/\text{s}$

XII. Result(s)

1. Delivery pressure = $\dots\dots\dots$ Bar.
2. Density of air = $\dots\dots\dots$ kg/m^3 .
3. F.A.D. = $\dots\dots\dots$ $\text{ m}^3/\text{s}$.

XVI. References/Suggestions for further reading

- Working of single-stage reciprocating air compressor: <https://www.youtube.com/watch?v=kFQu9uoZWKg>
- Working of two-stage reciprocating air compressor: <https://www.youtube.com/watch?v=yLWzBuk5lRs>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the measuring Instruments	20%
2	Noting the Observations	20%
3	Calculation of final readings	20%
Product Related (10 Marks)		(40%)
4	Interpretation of result	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 17: Test on two-stage reciprocating air compressor (Part II)

I. Practical Significance

Compressed air is required for a variety of applications like inflation of vehicle tyres, spray painting, bore-well, fettling tools in foundry, pneumatic clamps in machines, cleaning in machine shop, food packaging, mining tools, automobile service tools, etc. So, the air compressor becomes essential utility equipment in most industries that have almost continuous operation. It takes in the atmospheric air, compresses and delivers it to the machines or equipment at the required pressure and rate of air discharge. A reciprocating air compressor is capable of providing air at higher pressure, which increases with the number of compressor stages. Selection of the appropriate compressor, which fulfills the requirement of such applications pertaining mainly to air pressure and flow rate, consuming less energy, demands knowledge and skill to test the performance of the air compressor for the parameters of delivery pressure, capacity, drive power, efficiency, etc.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer: 'Select and maintain reciprocating air compressor for the desired industrial application.'

III. Course Level Learning Outcome (s)

CO3 - Analyze the performance of air compressor.

IV. Laboratory Learning Outcome(s)

- Calculate pressure ratio, volumetric efficiency & isothermal efficiency.
- Draw the performance characteristics.

V. Relative Affective Domain-related Outcome(s)

- Demonstrate working as a leader/a team member.
- Maintain tools and equipment.
- Follow ethical Practices.

VI. Relevant Theoretical Background

Terms related to air compressor:

- a) Pressure Ratio – It is the ratio of discharge pressure to the suction pressure.
- b) Volumetric efficiency – It is the ratio of the actual volume of air sucked in by the compressor during the suction stroke to the swept volume of the cylinder.
- c) Isothermal Efficiency – It is the ratio of isothermal work of compression to the indicated work of compression.
- d) Mechanical efficiency – It is the ratio of the actual or indicated power required for the compression of air to the driving power supplied at the compressor shaft.

Performance characteristics of compressor:

Effectiveness of intercooler:

Perfect intercooling –

If the intercooler brings down the air temperature back to the suction temperature, intercooling is perfect. i.e., when $T_3=T_1$.

Imperfect intercooling –

If the intercooler is not able to bring down the air temperature back to the suction temperature, intercooling is imperfect. i.e. when $T_3>T_1$.

From the p-V diagram, we clearly see that the amount of compression work saved increases with the effectiveness of the intercooler, and perfect intercooling is most desirable.

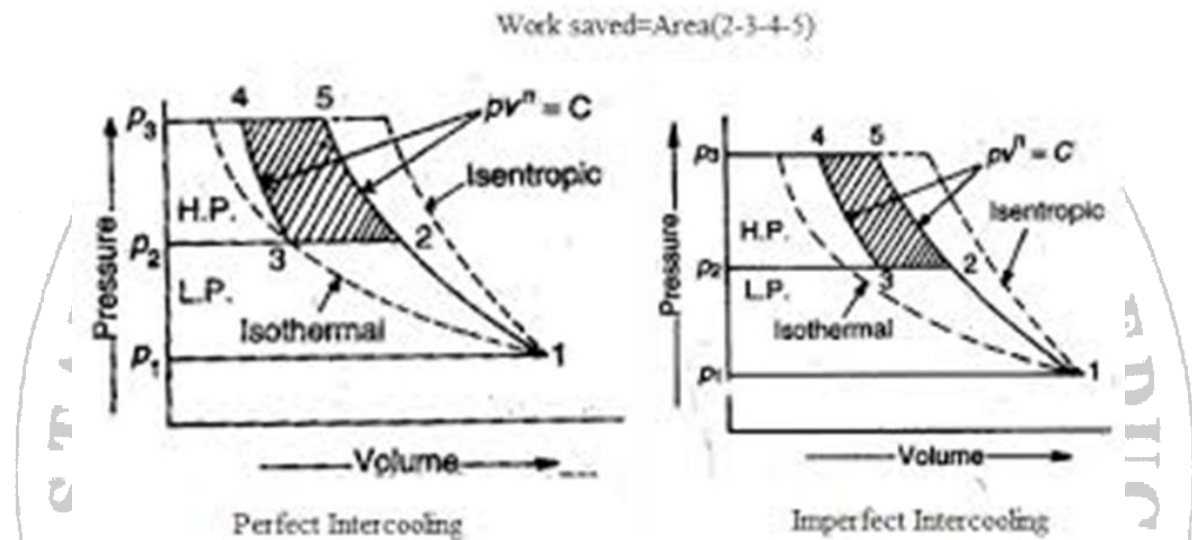


Figure 17.1 – P-V diagram for two-stage air compression with intercooling showing work saved during compression.

Comparison of compression process –

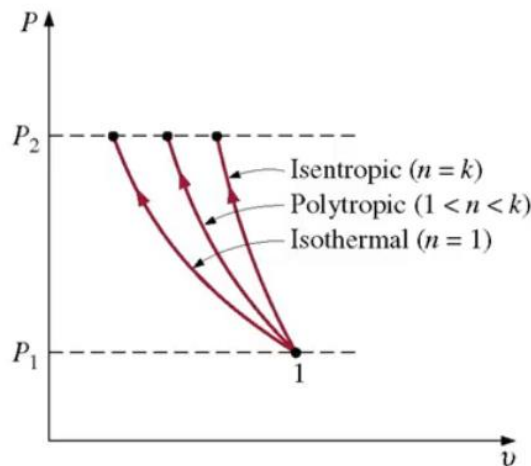


Figure 17.2 – P-V diagram showing types of compression processes

For a compressor, power consumption increases with the discharge pressure:

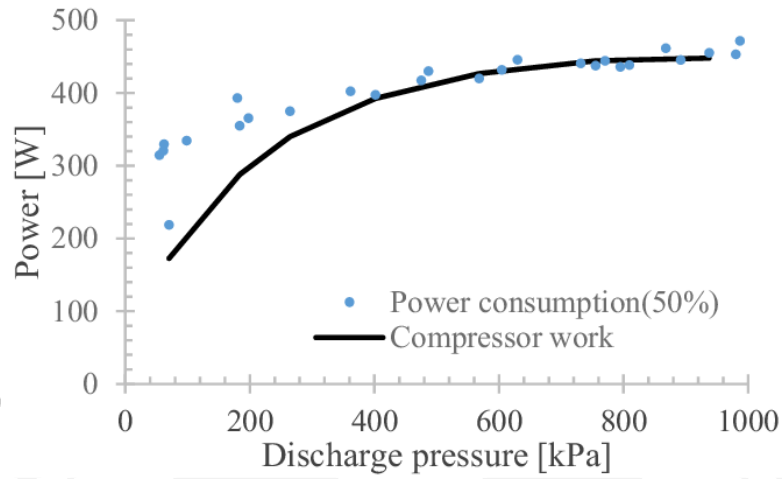


Figure 17.3 – Variation of compression power with discharge pressure

VII. Experimental setup

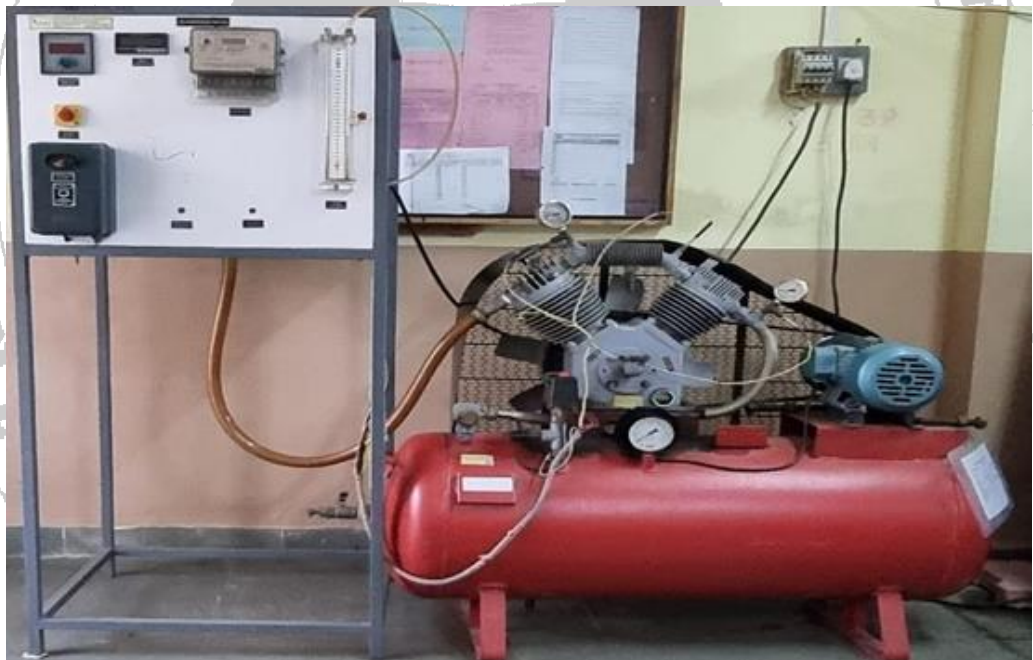


Figure 17.4 - Set up of two-stage reciprocating air compressor

VIII. Required Resources/apparatus/equipment with specifications

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Two-stage single-acting reciprocating air compressor with suitable motor drive	Speed 500 to 750 rpm. Delivery pressure of 7 to 10 kg/cm ² . Capacity about 200 to 300 LPM.	1
2	Pressure Gauge	Range -1 to 2 kg/cm ² for suction.	1
		Range 0 to 5 kg/cm ² for intercooler.	1
		Range 0 to 10 kg/cm ² for receiver.	1
3	Differential Manometer	U-tube water manometer	1
4	Air Box	About a 50-liter volume	1
5	Orifice plate	25 to 30 mm diameter fitted to air box	1
6	Thermometer or Thermocouple	Mercury in glass or type K	4
7	Digital temperature indicator	Pt100RTD 4-20 A range (in case of thermocouple)	1
8	Tachometer	Speed range 0 to 1500 rpm	1

IX. Precautions to be followed

- Check and maintain a proper level of lubricating oil in the compressor crankcase.
- Stay away from the moving and hot parts of the compressor.

X. Procedure

1. Fill the manometer with water up to half the level.
2. Keep the delivery valve and manometer cock on the suction line in closed position.
3. Start the compressor and open the manometer cock.
4. Let the air pressure build up in the air receiver.
5. Maintain the air pressure in the receiver constant by adjusting its air outlet valve. Note this delivery pressure reading shown by the pressure gauge mounted on receiver.
6. Measure and note down the motor speed using a tachometer, keeping this delivery pressure constant.
7. Note down water manometer reading, suction pressure, intercooler pressure, delivery pressure, suction temperature, temperatures before and after intercooler, and delivery temperature, keeping the same delivery pressure constant.

XI. Observations and calculations

1. Diameter of L.P. cylinder, $D_{LP} = \dots\dots\dots$ mm = $\dots\dots\dots$ m.
2. Diameter of H.P. cylinder, $D_{HP} = \dots\dots\dots$ mm = $\dots\dots\dots$ m.
3. Stroke length of L.P. and H.P. cylinders, $L_1 = L_2 = \dots\dots\dots$ mm = $\dots\dots\dots$ m.
4. Diameter of motor pulley, $(D_1) = \dots\dots\dots$ mm
5. Diameter of compressor pulley, $(D_2) = \dots\dots\dots$ mm

Observation Table

Sr. No.	Particulars	Notation	Unit	Reading value
1	Intake Pressure (gauge)	P_1 (gauge)	Kg/cm^2	
	Intake Pressure (absolute) $P_1(\text{abs}) = P(\text{atm}) + P_1(\text{gauge})$ $= (\dots\dots\dots) + (\dots\dots\dots \times 0.9806)$	P_1	bar	
2	Intercooler pressure (gauge)	P_2 (gauge)	Kg/cm^2	
	Intermediate Pressure (absolute) $P_2(\text{abs}) = P(\text{atm}) + P_2(\text{gauge})$ $= (\dots\dots\dots) + (\dots\dots\dots \times 0.9806)$	P_2	bar	
3	Delivery pressure (gauge)	P_3 (gauge)	Kg/cm^2	
	Delivery pressure (absolute) $P_3(\text{abs}) = P(\text{atm}) + P_3(\text{gauge})$ $= (\dots\dots\dots) + (\dots\dots\dots \times 0.9806)$	P_3	bar	
4	Intake temperature	t_1	$^{\circ}\text{C}$	
		$T_1 = t_1 + 273$	$^{\circ}\text{K}$	
5	Temperature before intercooler	t_1	$^{\circ}\text{C}$	
		$T_1 = t_1 + 273$	$^{\circ}\text{K}$	
6	Temperature after intercooler	t_1	$^{\circ}\text{C}$	
		$T_1 = t_1 + 273$	$^{\circ}\text{K}$	
7	Delivery temperature	t_1	$^{\circ}\text{C}$	
		$T_1 = t_1 + 273$	$^{\circ}\text{K}$	
8	Motor Speed	N_1	rpm	
9	Manometer reading	h_1	mm	
		h_2	mm	

Note: Write down here the observations from Practical No. 16.

Calculations:

A. Calculations for Pressure Ratio

1. First stage pressure ratio (L.P. Cylinder)

$$r_1 = P_2 / P_1 = \dots\dots\dots / \dots\dots\dots$$

$$= \dots\dots\dots$$

2. Second stage pressure ratio (H. P. Cylinder)

$$r_2 = P_3 / P_2 = \dots\dots\dots / \dots\dots\dots$$

$$= \dots\dots\dots$$

3. Compressor Pressure ratio

$$r = P_3 / P_1 = \dots\dots\dots / \dots\dots\dots$$

$$= \dots\dots\dots$$

Also, $r = r_1 \times r_2 = \dots\dots\dots \times \dots\dots\dots = \dots\dots\dots$

B. Calculations for Volumetric Efficiency

1. Actual volume of free air delivered

Note: Take this F.A.D. value (V_a) from Practical No. 16.

2. Compressor Speed

As a belt drive is used, we have $D_1 \times N_1 = D_2 \times N_2$

So, compressor Speed, $N_2 = D_1 \times N_1 / D_2 = \dots\dots\dots \times \dots\dots\dots / \dots\dots\dots = \dots\dots\dots$ rpm

Note: If the compressor is directly coupled to a motor, their speeds are equal.

3. Theoretical volume of air delivered in one cycle,

Volume of L.P. cylinder,

$$V_{LP} = (\pi/4) \times D_{LP}^2 \times L_1 = (\pi/4) \times (\dots\dots\dots)^2 \times \dots\dots\dots \text{ m}^3/\text{ cycle}$$

$$V_{LP} = \dots\dots\dots \text{ m}^3/\text{cycle}$$

4. Theoretical volume of air delivered per unit time

$$V_{th} = V_{LP} \times (N_2 / 60) = \dots\dots\dots \times (\dots\dots\dots / 60), \text{ m}^3/\text{s}$$

$$V_{th} = \dots\dots\dots \text{ m}^3/\text{s}.$$

5. Volumetric Efficiency

Volumetric efficiency = {(Actual volume of free air delivered) / Theoretical volume of free air delivered} \times 100

$$\eta_{vol} = (V_a / V_{th}) \times 100$$

$$= (\dots\dots\dots) / (\dots\dots\dots) \times 100$$

$$\eta_{vol} = \dots\dots\dots \%$$

C. Calculations for Isothermal Efficiency

1. Index of compression

Compression follows the polytropic process, i.e., $PV^n = C$

a) Value of compression index ‘n’ for 1st stage compression –

We know that for the compression process 1-2,

$$(T_1/T_2) = (P_1/P_2)^{(n-1/n)}$$

n = -----

b) Value of compression index ‘n’ for 2nd stage compression –

We know that for the compression process 2’-3

$$(T_2'/T_3) = (P_2/P_3)^{(n-1/n)}$$

n = -----

2. Actual work done

a) Work done in compressing air in a low-pressure (L.P.) cylinder

$$W_{LP} = (n/n-1) \times \{P_1 V_1 \times [(P_2/p_1)^{(n-1/n)} - 1]\}, J/s$$

$$= (n/n-1) \times \{m_a R_a T_1 \times [(P_2/P_1)^{(n-1/n)} - 1]\}, J/s \quad \text{where, } R_a = 287 \text{ J/kg}^\circ\text{K.}$$

$$W_{LP} = \text{-----} \text{ J/s}$$

b) Work done in compressing air in high-pressure (L.P.) cylinder

$$W_{HP} = (n/n-1) \times \{P_2 V_2 \times [(P_3/P_2)^{(n-1/n)} - 1]\}, J/s$$

$$= (n/n-1) \times \{m_a R_a T_2 \times [(P_3/P_2)^{(n-1/n)} - 1]\}, J/s \quad \text{where, } R_a = 287 \text{ J/kg}^\circ\text{K.}$$

$$W_{HP} = \text{-----} \text{ J/s}$$

Hence, actual work done or indicated work

$$W_{ind} = W_{LP} + W_{HP} = \dots + \dots$$

$$W_{ind} = \dots \text{ J/s}$$

3. Isothermal Work

$$W_{iso} = P_1 V_1 \times [\log_e(P_3/P_1)]$$

$$= m_a R_a T_1 \times [\log_e(P_3/P_1)] \text{ J/s}$$

$$= \dots$$

$$= \dots \text{ J/s or W}$$

$$= \dots \text{ kW.}$$

4. Isothermal efficiency

$$\eta_{iso} = (\text{Isothermal work/Indicated work})$$

$$= (W_{iso} / W_{ind}) \times 100$$

$$= (\dots / \dots) \times 100$$

$$= \dots \%$$

XII. Results

1. Compressor pressure ratio, $r = \dots$
2. Volumetric efficiency, $\eta_{vol} = \dots \%$
3. Isothermal efficiency, $\eta_{iso} = \dots \%$

XIII. Interpretation of results

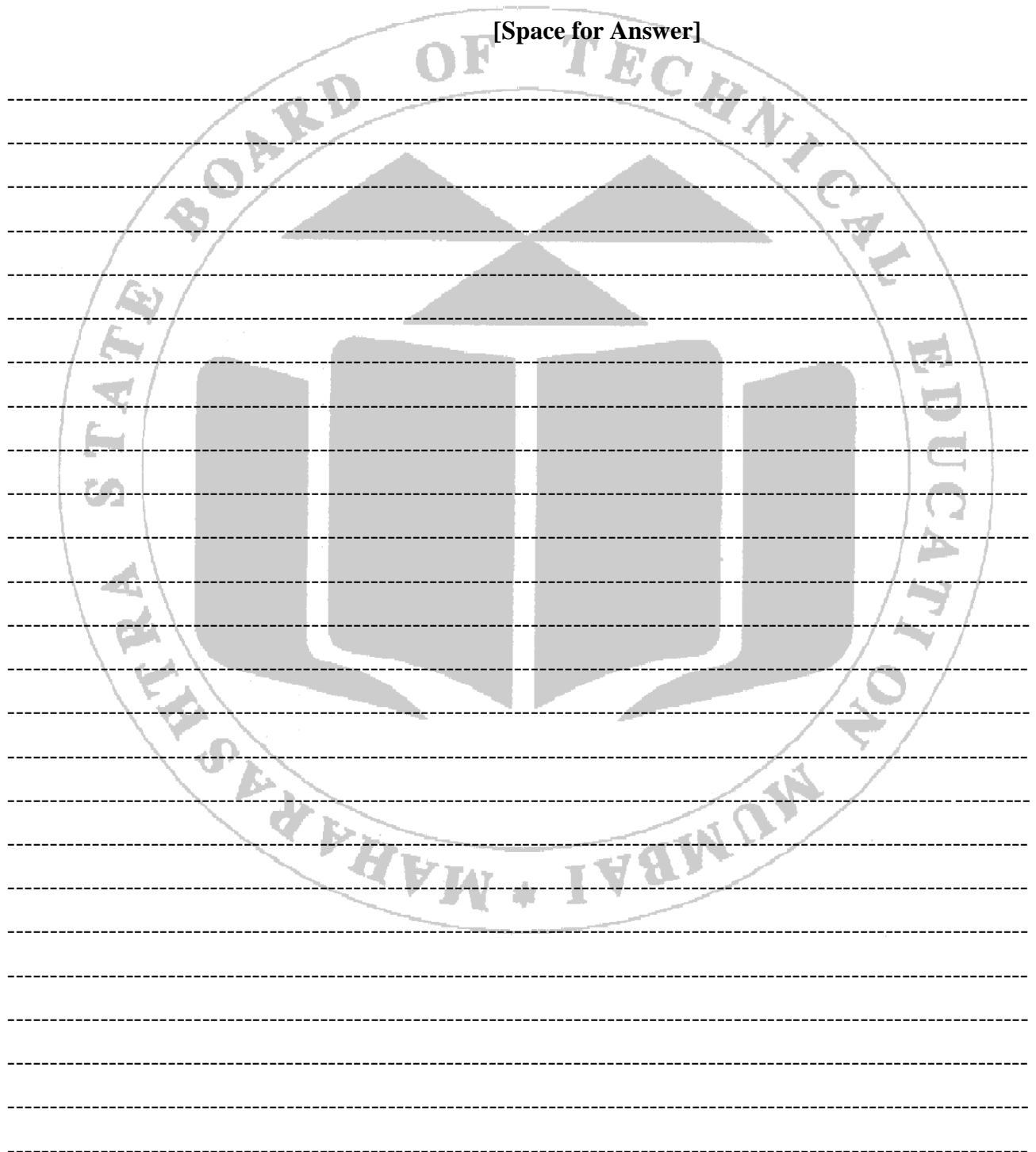
XIV. Conclusion and recommendation

XV. Practical-related questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Compare the amount of work of compression in the two stages. Put your comment.
2. State the factors that affect the compressor performance.
3. Calculate the percentage of power saved due to the two-stage compression against the single-stage compression having the same overall pressure ratio.
4. Explain how the clearance volume affects volumetric efficiency.
5. Explain the common causes that can lead to lower-than-expected volumetric efficiency in an engine

[Space for Answer]



Practical No. 18: Losses in the compressed air system

I. Practical Significance

Compressed air is widely regarded as the "fourth utility" in industries, essential for operating pneumatic tools, actuators, conveyors, and process equipment. However, it is one of the most inefficient energy systems, with typical energy losses ranging from 20% to 50%, primarily due to leaks, pressure drops, poor system design, and lack of maintenance. This practical enable student to inspect a compressed air system, identify various sources of losses, and understand their impact on the overall efficiency and cost of operation. By identifying and mitigating compressed air losses, students contribute to reduced greenhouse gas emissions and support global sustainability goals.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer: 'ability of students to identify and quantify different types of air losses within a compressed air system.

III. Course Level Learning Outcome (s)

CO5- Use the knowledge of energy saving in air compressor & refrigeration and air-conditioning systems.

IV. Laboratory Learning Outcome(s)

- Inspect the given compressed air system.
- Find out the sources of losses that occurred in the given compressed air system.

V. Relative Affective Domain-related Outcome(s)

- Demonstrate working as a leader/a team member
- Follow safety practices
- Understand the environmental impact of steam boilers.
- Follow ethical Practices.

VI. Relevant Theoretical Background

Principles of Compressed Air Systems:

A compressed air system generally includes an Air Compressor, which turns electrical (or mechanical) energy into pneumatic energy by compressing ambient air. Receiver Tank: Holds compressed air to handle demand changes and stabilize pressure. Distribution Network: Consists of pipes, fittings, filters, regulators, and valves that carry air to end-use equipment. End-use Devices: Pneumatic tools, actuators, conveyors, and more.

Types of Losses in Compressed Air Systems:

- A. Air Leakage: Unintended escape of compressed air through joints, fittings, hoses, and valves.
- B. Pressure Drop: Loss of pressure as air travels through pipes and components due to friction and obstructions.
- C. Heat Loss: Air compression generates heat. In a non-ideal (adiabatic) compression process, a significant portion of input energy is lost as heat (80–90%).

VII. Experimental setup



Figure 18.1 - Set up of two-stage reciprocating air compressor

VIII. Required Resources/apparatus/equipment with specifications

S. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Two-stage single-acting reciprocating air compressor with suitable motor drive	Speed 500 to 750 rpm. Delivery pressure of 7 to 10 kg/cm ² . Capacity about 200 to 300 LPM.	1
2	Pressure Gauges	0–16 bar, ±0.1 bar accuracy	1
3	Receiver Tank (Air Storage)	100–200 liters capacity, rated to 10 bars	1

IX. Precautions to be followed

- Do not operate the compressor without checking the oil
- Wear ear protection when the compressor is running.
- Ensure gauges are zeroed before taking readings.

X. Procedure

1. Turn ON the air compressor and allow it to build pressure up to the system's working pressure.
2. Observe pressure stabilization at the receiver tank.

3. Walk around the system and listen for hissing or whistling sounds, which may indicate air leaks.
4. Visually inspect joints, valves, and flexible hoses for damage or loose connections.
5. Use pressure gauges to record the air pressure at: Compressor outlet, Receiver tank, After filter unit, Before and after regulator, and at end-use points.
6. After completing leak detection, Turn OFF the compressor. Close the main outlet valve.

XI. Observation and calculations

Observation:

Sr. No	Measurement Point	Pressure (bar)	Remarks
1	Compressor Outlet (Receiver Input)		
2	After the Receiver Tank		
3	Before Filter Unit		
4	After Filter Unit		
5	Before Regulator		
6	After Regulator		
7	End-Use Point		

Calculation:

Total pressure drop in the system = Pressure at the compressor – Pressure at the end
 Outlet use point

= -----

= -----bar

XII. Result(s)

XIII. Interpretation of results

XVI. References / Suggestions for Further Reading

- <https://www.youtube.com/watch?v=4JiQ5XfpwfA>
- <https://www.iso.org/standard/46418.html>
- <https://beeindia.gov.in/sites/default/files/3Ch3.pdf>

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the measuring Instruments	20%
2	Taking readings of required parameters	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	

Practical No. 19: Energy saving in air-conditioning system

I. Practical Significance

With increasing urbanization and the widespread use of air conditioning in residential, commercial, and industrial buildings, HVAC (Heating, Ventilation, and Air Conditioning) systems make up a large portion of total electrical energy use. Therefore, even small improvements in the energy efficiency of air conditioning systems can result in significant savings on electricity bills and help reduce environmental impact. These practical enables students to understand, observe, and measure how operational strategies and maintenance practices affect energy consumption in AC systems.

II. Industry/Employer Expected Outcome (s)

This practical is expected to develop the following skills for the industry/Employer –

- Ability to assess and optimize the performance of HVAC systems for energy efficiency.
- Basic competence in monitoring air conditioning energy usage and implementing corrective actions.

III. Course Level Learning Outcome (CO)

CO5 - Use the knowledge of energy saving in air compressor & refrigeration and air-conditioning systems.

IV. Laboratory Learning Outcome(s)

- Inspect the air conditioning system.
- Prepare the checklist for energy efficiency.

V. Relative Affective Domain Related Outcome(s)

- Demonstrate working as a leader/a team member.
- Practice good housekeeping
- Follow ethical Practices.

VI. Minimum Theoretical Background

Energy saving in air conditioning systems is fundamentally based on understanding how these systems consume energy and how their performance can be optimized through design, operation, and maintenance strategies. Air conditioners work on the vapor compression refrigeration cycle, where energy is consumed mainly by the compressor to circulate refrigerant through the system and transfer heat from indoor air to the external environment. The Coefficient of Performance (COP) serves as a key performance indicator; higher COP values represent better efficiency with less energy consumed for the same cooling effect. Knowledge of psychometrics, including dry bulb and wet bulb temperatures, and relative humidity, is also necessary to assess thermal comfort and the effectiveness of cooling.

VII. Experimental setup



Fig 19.1 Window air conditioner



Fig 19.2 Split air conditioner

VIII. Required Resources /Apparatus/Equipment with specifications

Sr. No	Name of Resource	Suggested Broad Specification	Quantity
1	Air Conditioner	Split or Window AC, 1.5 Ton,5-Star BEE (Bureau of Energy Efficiency) Rated, Adjustable thermostat, fan speed settings, and timer	1
2	Digital Energy Meter	Single phase, 230V, 5–30A, class 1.0 accuracy.	1
3	Thermometer	Digital, -10°C to 50°C range	1
4	Hygrometer	Digital, 10% to 90% RH	1
5	Stopwatch	Digital, accurate to 1/100 sec	1
6	Lux Meter	Digital Light Meter, Range: 0–50,000 lux	1

IX. Precautions to be Followed

- Avoid frequent switching ON/OFF of the air conditioner.
- Ensure accurate placement of sensors for true readings.
- Allow the system to stabilize before taking readings.
- Ensure the test room remains closed during readings to minimize external load.

X. Procedure

1. Ensure that the test room is enclosed and has minimal air leakage.
2. Switch OFF all unnecessary heat-generating devices (lights, computers, fans) for initial baseline measurement.
3. Record the initial room temperature (dry bulb), relative humidity, and ambient temperature outside the room.
4. Note down the power reading on the digital energy meter.
5. Note down the initial fan speed, thermostat setting, and initial airflow condition.
6. Set the thermostat temperature to 24°C (recommended standard for energy efficiency).
7. Set the fan speed to medium or auto.
8. Close all doors and windows properly.
9. Start the air conditioner and stopwatch simultaneously.
10. Allow the system to run for 20 to 30 minutes.
11. Afterwards, record the Room temperature, Relative humidity, and Energy meter reading.
12. Increase the thermostat setting to 26°C and repeat the test for 30 minutes.
13. Afterwards, record the Room temperature, Relative humidity, and Energy meter reading.
14. Now reduce the thermostat to 22°C, repeat the test.
15. Compare the energy consumption across different thermostat settings to evaluate the most efficient one.
16. Open the blinds or curtains to allow sunlight in and record a 30-minute test.
17. Observe changes in room temperature rise, compressor run-time, and power usage.
18. Run tests at low, medium, and high fan speeds (keeping temperature constant at 24°C).
19. Note power readings and cooling comfort.

XI. Observations and calculations

Observations:

Thermostat Setting (°C)	Time of Operation (minutes)	Initial Energy Meter Reading (kWh)	Final Energy Meter Reading (kWh)	Energy Consumed (kWh)	Initial Room Temp (°C)	Final Room Temp (°C)	Initial RH (%)	Final RH (%)
22								
24								
26								

Effect of Thermostat Settings on Energy Consumption

Test Condition	Thermostat Setting (°C)	Time of Operation (minutes)	Initial Energy Meter Reading (kWh)	Final Energy Meter Reading (kWh)	Energy Consumed (kWh)	Initial Room Temp (°C)	Final Room Temp (°C)	Initial RH (%)	Final RH (%)
Blinds Open (Sunlight in)	24								
Blinds Closed (Curtains)	24								

Effect of Room Insulation / External Heat Load on Energy Consumption

Fan Speed Setting	Thermostat Setting (°C)	Time of Operation (minutes)	Initial Energy Meter Reading (kWh)	Final Energy Meter Reading (kWh)	Energy Consumed (kWh)	Initial Room Temp (°C)	Final Room Temp (°C)	Initial RH (%)	Final RH (%)
Low	24								
Medium	24								
High	24								

Effect of Fan Speed on Energy Consumption

Sr. No	Parameter	Observation/Remarks	Recommendation
1	Thermostat setting		
2	Fan speed		
3	Room insulation		
4	Sunlight Exposure		
5	AC Type		
6	Compressor ON time		

Energy Efficiency Checklist

Calculations:

I) For the Effect of Thermostat Settings

Energy Consumed (kWh)=Final Meter Reading (kWh)–Initial Meter Reading (kWh)

=

=kWh

$$\text{Energy Saving} = \frac{\text{Energy Consumption for initial thermostat setting} - \text{Energy Consumption for final thermostat setting}}{\text{Energy Consumption for the initial thermostat setting}} \times 100$$

=

=%

II) For the Effect of external load

Energy Consumed (kWh)=Final Meter Reading (kWh)–Initial Meter Reading (kWh)

=

=kWh

$$\text{Energy Saving} = \frac{\text{Energy Consumption (Blinds open)} - \text{Energy Consumption (Blinds closed)}}{\text{Energy Consumption (Blinds open)}} \times 100$$

=

=%

III) For the Effect of Fan Speed

Energy Consumed (kWh)=Final Meter Reading (kWh)–Initial Meter Reading (kWh)

=

=kWh

$$\text{Energy Saving} = \frac{\text{Energy Consumption (Low fan speed)} - \text{Energy Consumption (High fan speed)}}{\text{Energy Consumption (Low fan speed)}} \times 100$$

=

=%

XII. Results

XIII. Interpretation of Results

XIV. Conclusions and Recommendations

XV. Practical Related Questions

1. Write the purpose of a thermostat in an air conditioning system.
2. List any two energy-saving devices used in air conditioners.
3. Explain why it is important to keep doors and windows closed when the AC is on.
4. Suggest ways to reduce AC energy consumption in an office building.
5. Enlist the causes of reduced C.O.P. in older AC systems.

[Space for Answer]

XVII. Rubrics for Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		(60%)
1	Handling of the measuring Instruments	20%
2	Taking readings of required parameters	20%
3	Observation and Recording Skills	20%
Product Related (10 Marks)		(40%)
4	Logical Analysis of Observations	10%
5	Conclusions	10%
6	Practical related questions	20%
Total		100 %

Marks Obtained			Dated signature of Teacher
Process Related (15)	Product Related (10)	Total (25)	