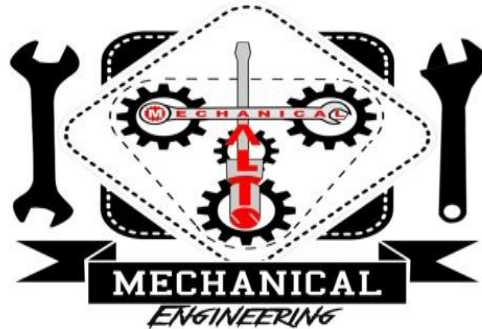


**ANANTHA LAKSHMI
INSTITUTE OF TECHNOLOGY & SCIENCES**

**JNTUA Affiliated, AICTE Approved, NAAC Accredited
Near S.K. University, Itukalapalli, Anantapur, Andhra Pradesh - 515721**



APPLIED THERMODYNAMICS LAB MANUAL

(Course code : 20A0340)

**PREPARED
BY**

Dr. P. NAGASUBBA RAYUDU M.Tech, Ph.D.

Professor and Dean Academics

DEPARTMENT OF MECHANICAL ENGINEERING

VISION OF THE DEPARTMENT:

To produce competent global mechanical engineers who can solve industrial and societal problems with technology, innovation, environment and ethical spirits.

MISSION OF THE DEPARTMENT:

The Vision will be attained by

- Providing quality teaching-learning methods combining with modern pedagogies.
- Developing the laboratories & infrastructure as practice labs with modern equipment and imparting skill based training.
- Encouraging and enriching the faculty to learn & teach advanced technologies through faculty development programs & international conferences.
- Motivating and encouraging the students to acquire the graduate attributes through workshops, seminars, conferences, innovative projects, internships and industrial trainings.

PROGRAMME EDUCATIONAL OBJECTIVES (PEO):

The following are the Program Educational objectives (PEOs) of the Mechanical Engineering Graduates: The Mechanical engineering program is designed to produce students for successful careers in manufacturing & service Industry, research & consultancy at the national and global level. Our Graduates are expected to:

PEO I:Apply their engineering knowledge combining with graduate attributes to develop technology-based solutions in professional engineering practice and also non-engineering fields such as agriculture, society, and environment.

PEO II:Develop their intellectual quotient through higher educations and online courses.

PEO III:Adapt leadership roles as Intrapreneur and entrepreneur.

PROGRAMME OUTCOMES (PO):

The following are the Program Outcomes (POs) of Mechanical Engineering Graduates:

PO1: Engineering knowledge - Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and teamwork: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

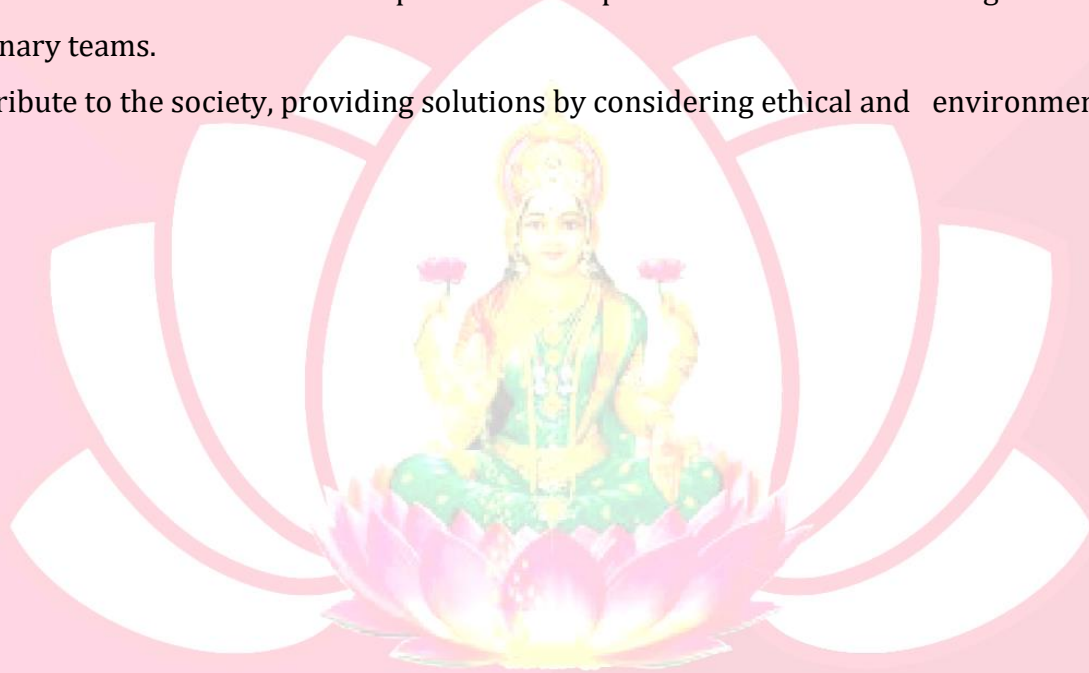
PROGRAMME SPECIFIC OUTCOMES (PSO):

The following are the Program Specific Outcomes (PSOs) of Mechanical Engineering Graduates:

PSO-1: Apply the knowledge of materials, product design, simulation and manufacturing to solve mechanical domain related problems.

PSO-2: Enable to work in innovative and product development themes collaborating with multidisciplinary teams.

PSO-3: Contribute to the society, providing solutions by considering ethical and environmental policies

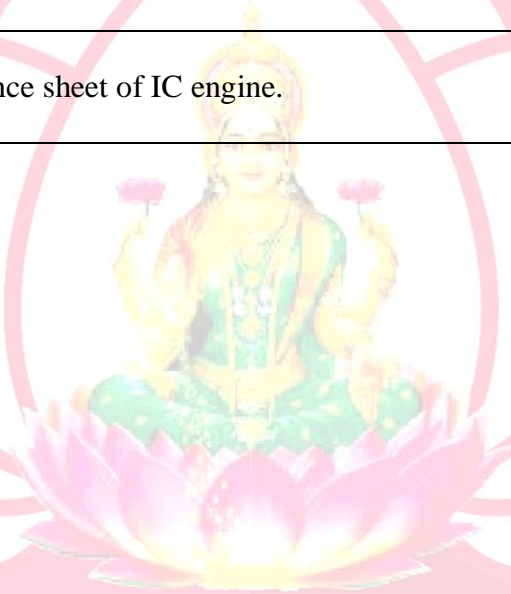


ALTS



COURSE OUTCOMES

C01	Explain different working cycles of engine
C02	Describe various types of combustion chambers in IC engines
C03	Illustrate the working of refrigeration and air conditioning systems
C04	Evaluate heat balance sheet of IC engine.



ALTS



PREFACE:

The primary purpose of the laboratory 'ATD' is to show students the experimental methods on thermal energies on various engines and demonstrate their operational procedures. These values can be further used to determine other fuel properties. In order that students have a fairly good understanding of the theory underlying the experiments, the entire course is designed such that classroom lectures precede lab work. Students are advised to pay close attention in class so that they can perform well in the lab.

LAB POLICY GROUPS:

Students will be formed into groups of three or four on the first lab day. Once a student has signed up with a group, he or she may not change groups without prior approval of the instructor.

LAB REPORTS:

- You will perform the experiment in group, and turn in ONE REPORT PER GROUP.
- Your report should be self-contained, i.e. an engineering technologist should be able to perform the experiment and duplicate your results by reading your report.
- DO NOT "adjust" your data to make them fit what you believe to be an acceptable value. Your report should be an accurate description of the experiment.
- If your results differ significantly from reference values you should check your settings carefully (calibration, wrong units, wrong calculations, etc.), and do the experiment again.
- Try to explain any discrepancies but do not "adjust" your data.

REPORT FORMAT:

The report must be hand written. A report should include the following in order

A. A title page, which includes the following information, in order:

1. Course Number and Section Number
2. Experiment Title
3. Names of the Group Members (who contributed to do the lab/report)
4. Due Date

B. Objective or purpose of the experiment work.

C. Theoretical aspect of the experiment.

D. Experimental procedure that explains briefly the procedure of how the experiment was performed and all the equipment used.

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E. Experimental and/or calculated results. (Include all data you have taken, a sample calculation, and the results) The result table must be presented in tabular form. Also, all calculations and graphical work (e.g. graph) must be hand written/drawn.

F. Discussion of results in light of the theoretical “predictions”. Include an error analysis. Quantify the errors whenever possible.

G. Conclusions, wherein you write what you learned from the experiment. Your conclusions must summarize your report and must be based on your experimental results.

H. Lab reports are due at the beginning of next lab. Late lab reports will not be accepted.

Note: In order to get a good grade in the lab, please follow the instructions listed below:

1. Read about the lab prior to the beginning of the lab. Do each lab with an attitude of learning.
2. Please bring your lab manual to the lab. Each group should have at least one lab manual with them.
3. Students are advised to bring blank and graph papers to the lab, on which you can do calculations and draw graphs.
4. Remember, the lab grade is 20% of your final grade. Doing well in lab will help you in getting a good overall course grade. Remember,

“Nothing worthwhile will ever be achieved without deep thought and hard work”

ATTENDANCE:

Attendance will be taken at the beginning of every lab session.

THERMAL ENGINEERING LAB POLICY:

We want to maintain the high quality conditions of this lab for the students in future years. Thus, it is necessary for you to adhere to the established policy of NO BEVERAGES, FOOD, NEWS PAPERS, MAGAZINES, TOBACCO PRODUCTS AND ANIMALS within the Thermal Engineering lab.

SAFETY:

For your own safety, please wear the pants and shoes that cover toes for this Lab. The safety goggle will be needed for several labs.

GENERAL INSTRUCTIONS:

1. Every student should obtain a copy of the laboratory manual.
2. Dress code: Students must come to the laboratory wearing:
 - (i) Trousers,
 - (ii) Half-sleeve tops and
 - (iii) Leather shoes.

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3. To avoid any injury, the student must take the permission of the laboratory staffs before handling the machines.
4. **EVERY STUDENT IS REQUIRED TO HANDLE THE EQUIPMENT WITH CARE.**
5. Students must ensure that their work areas are clean.
6. At the end of each experiment, the student must take initials from the staff on your data/observations.
7. Laboratory report must be submitted in standard sheet, available at stores in the subsequent lab turn. Reports on ordinary sheets and computer papers will not be accepted.
8. Each member of any group must submit lab report even if the experiment has been performed in a group.
9. The lab report must contain:
 - I. Title of the experiment,
 - II. Three to four lines stating the objectives,
 - III. A few lines on background;
 - IV. Name of all equipments/tools used along with one line description of its use
 - V. Neatly labeled sketches.
10. Student can check their laboratory reports after correction for discussion.

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Applied Thermodynamics Lab (20A03401P)

LIST OF EXPERIMENTS

S.NO	NAME OF THE EXPERIMENT
1	Valve timing diagram of 4-stroke diesel engine
2	Port timing diagram of 2-stroke petrol engine
3	Performance of 2-stroke single cylinder petrol engine
4	Morse test on multi cylinder petrol engine
5	Performance of 4-stroke single cylinder diesel engine
6	Assembly and disassembly of diesel and petrol engines
7	Exhaust gas analysis
8	Performance of two stage reciprocating air compressor
9	Determination of nozzle characteristics
10	Performance of Refrigeration system
11	Performance of Air conditioning system
12	Performance of heat pump

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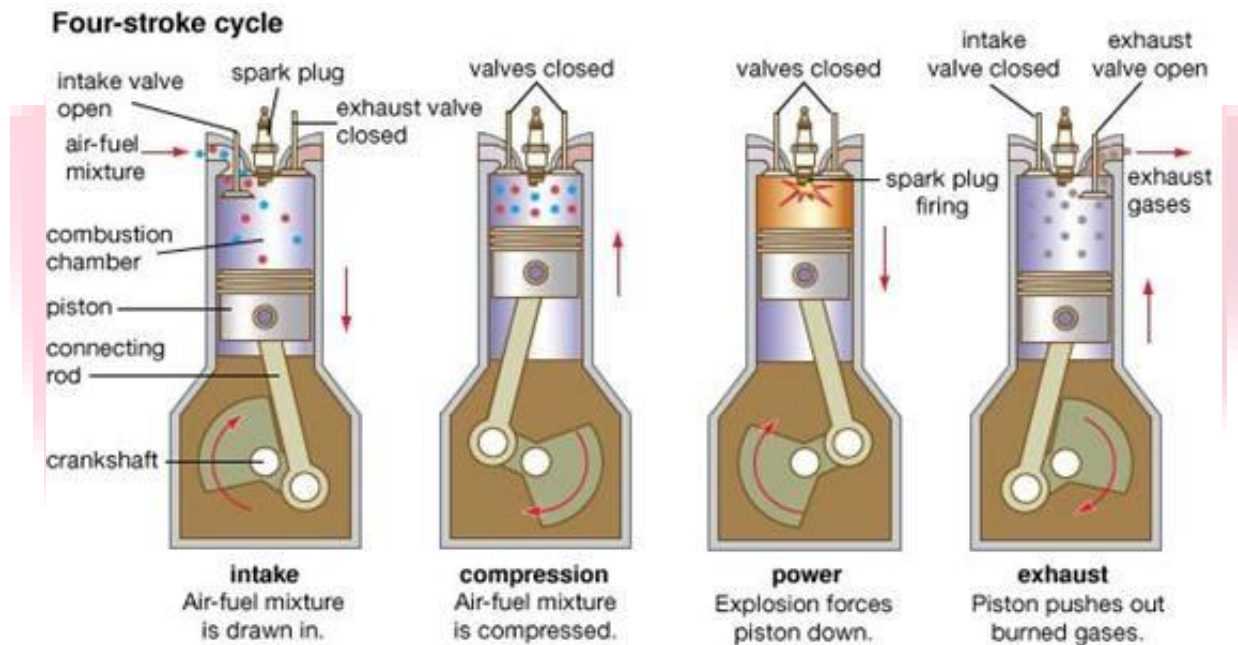
I.C. ENGINE VALVE TIMING DIAGRAM **(FOUR - STROKE CYCLE DIESEL ENGINE)**

INTRODUCTION ABOUT FOUR - STROKE CYCLE DIESEL ENGINE:

It is also known as compression ignition engine because the ignition takes place due to the heat produced in the engine cylinder at the end of compression stroke. The four strokes of a diesel engine sucking pure air are described below:

- **Suction or charging stroke:** In this stroke, the inlet valve opens and pure air is sucked into the cylinder as the piston moves down wards from the top dead center (TDC). It continues till the piston reaches its bottom dead center (BDC) as shown in the Figure (a).
- **Compression stroke:** In this stroke, both valves are closed on the air is compressed as the piston moves upwards from BDC to TDC. As a result compression, pressure and temperature of the air increases considerably (the actual value depends upon the compression ratio). This completes one revolution of the crank shaft. The compression stroke is shown in Figure (b).
- **Expansion (or) working stroke:** Shortly before the piston reaches the TDC (during the compression stroke), fuel oil is injected in the form of very fine spray into the engine cylinder, through the nozzle, known as fuel injection valve. At this moment, temperature of the compressed air is sufficiently high to ignite the fuel. It suddenly increases the pressure and temperature of the products of combustion. The fuel oil is continuously injected for a fraction of the revolution. The fuel oil is assumed to be burnt at constant pressure. Due to increased pressure, the piston is pushed down with a great force. The hot burnt gases expand due to high speed of the piston. During this expansion, some of the heat energy is transformed into mechanical work. It may be noted that during the working stroke, both the valves are closed and the (Piston moves from T.D.C to B.D.C (as shown in figure (c))

- **Exhaust stroke:** In this stroke, the exhaust valve is open as the piston moves from BDC to TDC. This movement of the piston pushes out the products of combustion from the engine cylinder through the exhaust valve into the atmosphere. This completes the cycle and the engine cylinder is ready to suck the fresh air again. (as shown in Figure (d)).



VALVE TIMING DIAGRAM FOR A FOUR-STROKE CYCLE DIESEL ENGINE:

- In the valve timing diagram as shown in Figure, we see that the inlet valve opens before the piston reaches TDC; or in other words while the piston is still moving up before the beginning of the suction stroke. Now the piston reaches the TDC and the suction stroke starts.
- The piston reaches the BDC and then starts moving up. The inlet valve closes, when the crank has moved a little beyond the BDC. This is done as the incoming air continues to flow into the cylinder although the piston is moving upwards from BDC. Now the air is compressed with both valves closed. Fuel valve opens a little before the piston reaches the TDC.
- Now the fuel is injected in the form of very fine spray, into the engine cylinder, which gets ignited due to high temperature of the compressed air. The fuel valve closes after the piston has come down a little from the TDC. This is done as the required quantity of fuel is injected into the engine

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cylinder. The burnt gases (under high pressure and temperature) push the piston downwards, and the expansion or working stroke takes place.

- Now the exhaust valve opens before the piston again reaches BDC and the burnt gases start leaving the engine cylinder. Now the piston reaches BDC and then starts moving up thus performing the exhaust stroke.
- The inlet valve opens before the piston reaches TDC to start suction stroke. This is done as the fresh air helps in pushing out the burnt gases. Now the piston again reaches TDC, and the suction starts.
- The exhaust valve closes when the crank has moved a little beyond the TDC. This is done as the burnt gases continue to leave the engine cylinder although the piston is moving downwards.

TDC - Top Dead Center

BDC - Bottom Dead Center

FIS - Fuel Injection Starts

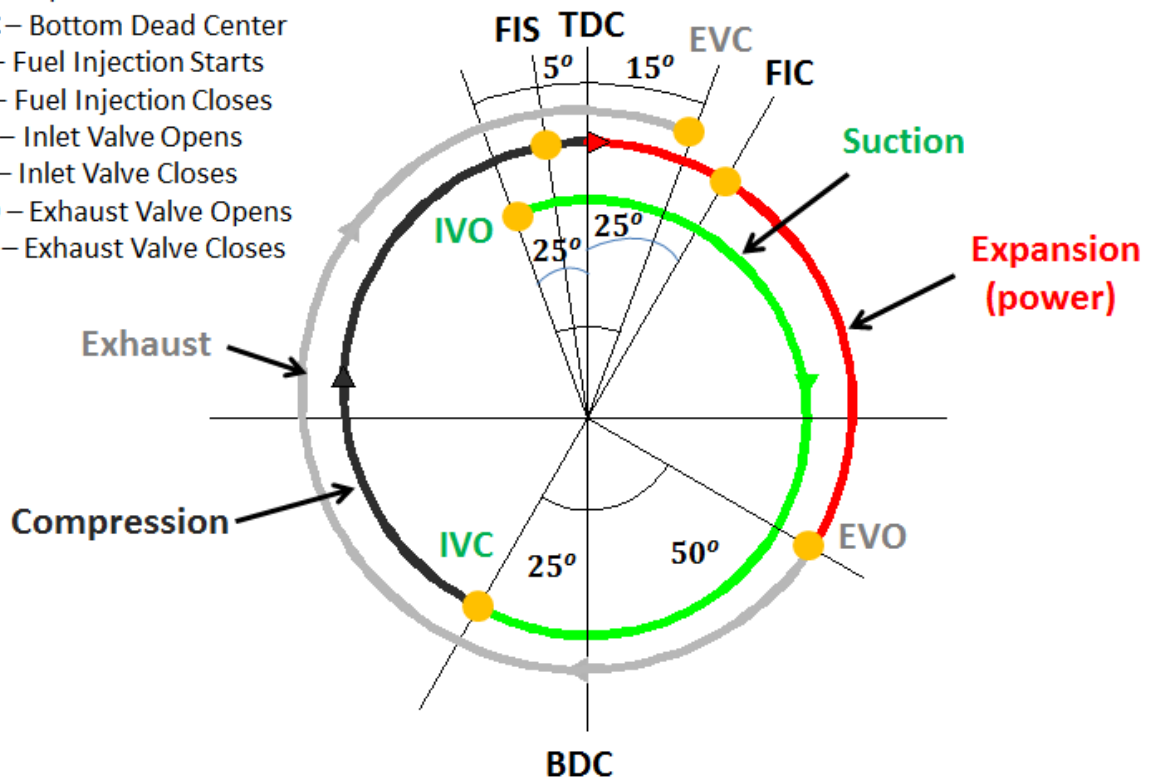
FIC - Fuel Injection Closes

IVO - Inlet Valve Opens

IVC - Inlet Valve Closes

EVO - Exhaust Valve Opens

EVC - Exhaust Valve Closes



VALVE TIMING DIAGRAM

Experiment No: 01

Date:

I.C. ENGINE VALVE TIMING DIAGRAM **(FOUR - STROKE CYCLE DIESEL ENGINE)**

AIM:

To conduct valve timing test on a four stroke single cylinder diesel engine to find out the suction, compression, expansion, exhaust and valve overlap periods, to draw the valve timing diagram, and explain the reasons of deviation from the theoretical timings.

APPARATUS:

- Piece of Thread.
- Scale – Steel Rule
- Chalk Piece.
- Cut section model of Four – Stroke Single Cylinder Vertical Diesel Engine.

Specifications:

- Engine type = CI engine
- Cycle of operation = Four stroke Diesel Engine
- Model = Cut Section Model

THEORY:

Valve timing is the determination of points in the cycle at which the valves are set to open and close. In the ideal cycle the inlet and exhaust valves open at dead centers. There are two factors: Mechanical and Dynamical for the actual valve timing to be different from the theoretical valve timing.

A. Mechanical Factor:

The valves of a reciprocating engine are opened closed by cam mechanism. To avoid noise and wear, the valve should be lifted slowly. For the same reason the valve cannot be closed abruptly else it will bounce on its seat. Then the opening and closing periods are spread over a considerable number of crank shaft degrees. As a result the opening of the valve must commence a head of time at which it is fully opened. The same reason applied for the closing time and valve must close after dead centers.

B. Dynamic Factor:

Besides the mechanical factor the actual valve timing is set taking the dynamic effects of gas flow into consideration. As the piston moves all in the suction stroke, the fresh air is drawn into the cylinder through the inlet valve when the piston reaches the BDC and to move towards TDC in the

compression stroke, the inertia of the centering fresh air tends to cause to continue to move in the cylinder after BDC. So, maximum air is taken in to the cylinder portion.

The exhaust valve is set to open before BDC. By earlier opening of the exhaust valve, the scavenging period is increased. Also earlier opening means that exhaust pressure is higher than the atmospheric pressure, which helps in scavenging process. The exhaust valve is closed a few degrees after TDC.

The inertia of the exhaust gases tends to scavenge the cylinder by carrying out a greater mass gas lift in Clearance volume. For some period there is valve overlapping i.e., the kinetic energy of fresh charge helps in forcing out at exhaust gases.

PROCEDURE:

1. T.D.C. is identified and marked on the fly wheel with respect to one fixed point in the engine.
2. The circumference of fly wheel is measured using thread and scale.
3. The BDC is marked on the flywheel by taking half the circumference.
4. The cover on the valve casing is removed and inlet and exhaust valves and their push rods are identified.
5. By slowly cranking the camshaft in the direction of rotation the opening of inlet valve is marked on the fly wheel w.r.t. fixed point when the push rod of inlet fixed point when the push rod of inlet valve is becomes tight to move.
6. Mark a point on the fly wheel where the inlet valve is completely closed.
7. In the same way mark the points where the exhaust valve open and close.
8. The distance of opening of inlet valve and closing of exhaust valve from TDC and closing of inlet valve and opening of the exhaust valve from BDC are measured using thread and scale.
9. The angles of opening and closing of inlet and exhaust valves are calculated w.r.t. TDC and BDC.

PRECAUTIONS:

1. The decompression level must be operated when conducting the test.
2. Cranking should be the carefully and slowly so that the salient points are located carefully.

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OBSERVATIONS:

Circumference of the fly wheel = $2 \pi R$

Sl. No.	Event	Arc Length (Distance from nearest dead center)		Angle 'θ' in degrees
		In Centimeters	In Millimeters	
1	Inlet valve open (IVO) - TDC			
2	Inlet valve close (IVC) - BDC			
3	Exhaust valve open (EVO) - BDC			
4	Exhaust valve close (EVC) - TDC			

Specimen Calculations:

1. Diameter of the flywheel (D) is given by,

$$D = \frac{\text{Circumference of the fly wheel}}{\pi} = 39.47 \text{ cmts}$$

2. Angle 'θ' in degrees is given by,

$$\theta = \frac{S * 360}{\pi * D}$$

Where,

S = Arc length in mm

RESULT:

The observations of the Valve - Timing Diagram is listed below:

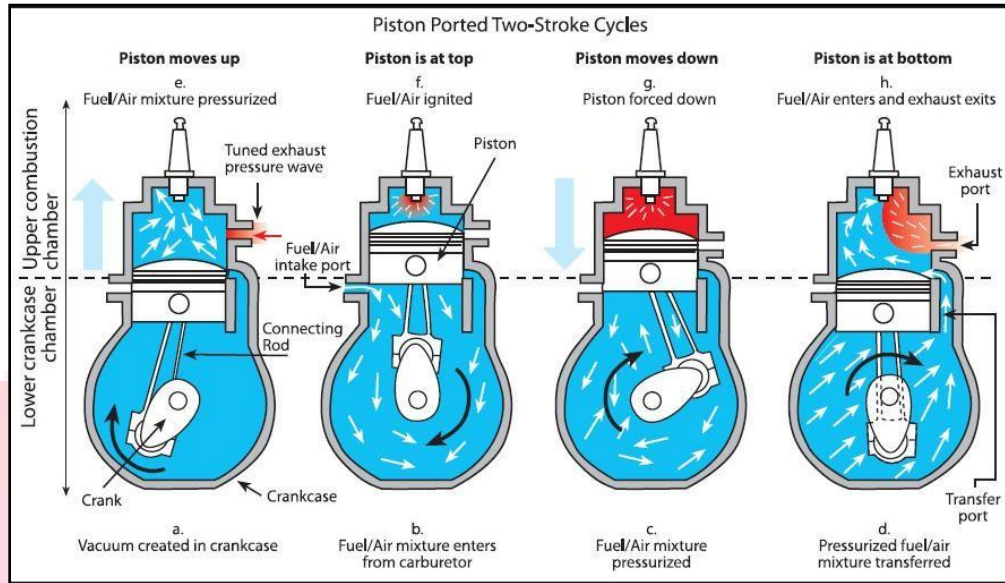
- Angle at Inlet valve open (IVO) - Before TDC = _____
- Angle at Inlet valve close (IVC) - After BDC = _____
- Angle at Exhaust valve open (EVO) - Before BDC = _____
- Angle at Exhaust valve close (EVC) - After TDC = _____
- Valve Timing diagram is drawn

I.C. ENGINE PORT TIMING DIAGRAM

INTRODUCTION ABOUT TWO – STROKE CYCLE PETROL ENGINE:

A Two-Stroke cycle petrol engine was devised by Duglad Clerk in 1880. In this cycle, the suction, compression, expansion and exhaust takes place during two strokes of the piston. It means that there is one working stroke after every revolution of the crank shaft. A two stroke engine has ports instead of valve. All the four stages of a two petrol engine are described below:

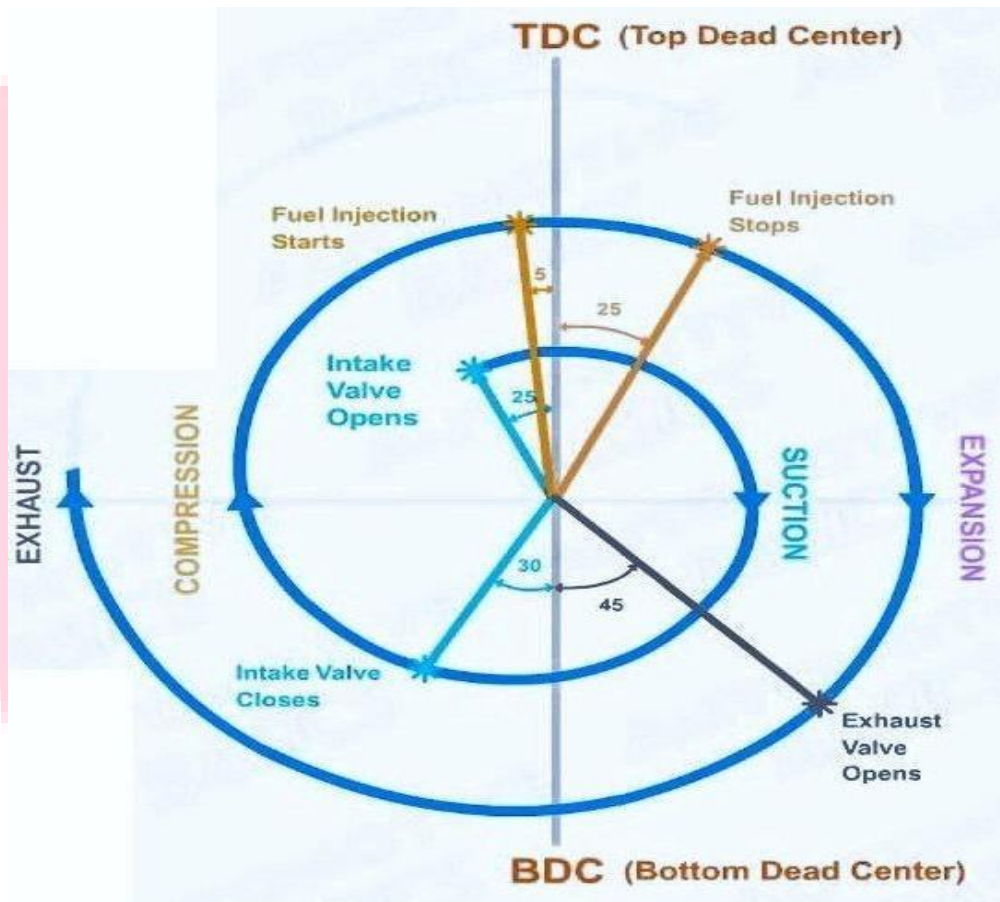
- **Suction stage:** In this stage, the piston, while going down towards BDC, uncovers both the transfer port and the exhaust port. The fresh fuel-air mixture flows into the engine cylinder from the crank case, as shown in the Figure-(a).
- **Compression stage:** In this stage, the piston, while moving up, first covers the transfer port and then exhaust port. After that the fuel is compressed as the piston moves upwards as shown in the Figure-(b). In this stage, the inlet port opens and fresh fuel air mixture enters into the crank case.
- **Expansion stage:** Shortly before this piston reaches the TDC (during compression stroke), the charge is ignited with the help of a spark plug. It suddenly increases the pressure temperature of the products of combustion. But the volume, practically remains constant. Due to rise in the pressure, the piston is pushed downwards with a great force a shown in Figure-(c). The hot burnt gases expand due to high speed of the piston. During the expansion, some of the heat energy produced is transformed into mechanical work.
- **Exhaust stage:** In this stage, the exhaust port is opened as the piston moves downwards. The products of combustion, from the engine cylinder are exhausted through the exhaust port into the atmosphere, as shown in the Figure-(d). This completes the cycle and the engine cylinder is ready to suck the charge again.



PORT TIMING DIAGRAM FOR A TWO-STROKE CYCLE PETROL ENGINE:

- In the Port timing diagram, as shown in the Figure, we see that the expansion of the charge (after ignition) starts as the piston moves from TDC towards BDC.
- First of all, the exhaust port opens before the piston reaches BDC and the burnt gases start leaving the cylinder. After a small fraction of the crank revolution, the transfer port also opens and the fresh fuel-air mixture enters into the engine cylinder. This is done as the fresh incoming charge helps in pushing out the burnt gases.
- Now the piston reaches BDC, and then starts moving upwards. As the crank moves a little beyond BDC, first the transfer port closes and then the exhaust port also closes. This is done to suck fresh charge through the transfer port and to exhaust the burnt gases through the exhaust port simultaneously.
- Now the charge is compressed with both ports closed, and then ignited with the help of a spark plug before the end of compression stroke. This is done as the charge requires some time to ignite.

- By the time the piston reaches TDC, the burnt gases (under high pressure and temperature) push the piston downwards with full force and expansion of the burnt gases takes place. It may be noted that the exhaust and transfer ports open and close at equal angles on either side of the BDC position.



PORT TIMING DIAGRAM

Experiment No: 02

Date:

I.C. ENGINE PORT TIMING DIAGRAM **(TWO - STROKE CYCLE PETROL ENGINE)**

AIM:

To conduct the port timing diagram test on a cut section model of a single cylinder two stroke petrol engine to find out the suction, compression, expansion and exhaust periods, and to draw the port timing diagram.

APPARATUS

- Piece of Thread.
- Scale - Steel Rule
- Chalk Piece.
- Cut section model of Two - Stroke Single Cylinder Petrol Engine.

SPECIFICATIONS:

- Engine type = SI engine
- Cycle of operation = Two Stroke Petrol Engine
- Model = Cut Section Model

THEORY:

Ignition and expansion takes place in the usual way. During the expansion stroke, the air in the crank case is coin a two stroke engine, the cycle is completed in two strokes i.e. one revolution of crank shaft as against two revolutions of a four stroke cycle.

The difference between two stroke and four stroke engine is, in the method of filling cylinder with fresh charge and removing the burnt gases from the cylinder. In a four stroke engine, these operations are performed by the engine piston during suction and exhaust strokes respectively. In a two stroke engine, suction is accomplished by air compression in crank.

The induction of compressed air removes the products of combustion, through exhaust port. Therefore, no piston strokes are required for these two operations. Only two piston strokes are required to complete the cycle, one for compression of fresh charge and the other for power stroke.

The air or charge is sucked through spring loaded inlet valves when the pressure in the crank cases reduces due to upward motion of the piston during compression stroke.

After the compression pressed, near the end of the expansion stroke piston uncovers the exhaust ports and the cylinder pressure drops to atmospheric values as the combustion products leave the cylinder.

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Further motion of the piston uncovers the transfer port, permitting the slightly compressed air or mixture in the crank case to enter the engine cylinder. The top of the piston usually has a projection to deflect the fresh air to sweep up to the top of the cylinder, before flowing to the exhaust ports.

This serves the double purpose of scavenging the upper part of the cylinder of combustion products and preventing the fresh charge from flowing directly to the exhaust ports. The same objective can be achieved without piston deflector by proper sloping of the transfer port.

During the upward motion of the piston from BDC, the transfer and exhaust ports close, compression of charge begins and cycle is repeated

PROCEDURE:

The cycle of operation proceeds as suction, compression, power and exhaust strokes takes place in series.

1. Initially the circumference of the flywheel is measured. A pointer is attached above the flywheel such that it coincides with B.D.C marked on the flywheel at the starting of the engine .This pointer is used for marking specific points. The duration of each stroke theoretically is 90° , but since the actual span varies, the port timings are to be individually measured.
2. The flywheel is rotated .The instant at which inlet port starts to open is determined and corresponding point is marked on flywheel . This when converted to degrees gives IPO.
3. The position when the piston completely closes the inlet port is marked as IPC.
4. The points EPO and EPC corresponding to exhaust port opening and exhaust port closing are marked similar to that of IPO and IPC.
5. The position when the transfer port opens and closes is marked as TPO and TPC.

OBSERVATIONS:

Circumference of the fly wheel = $2 \pi R$

Sl. No.	Event	Arc Length (Distance from nearest dead center)		Angle 'θ' in degrees
		In Centimeters	In Millimeters	
1	Transfer Port open			
2	Transfer Port Close			
3	Exhaust Port open			
4	Exhaust Port Close			

Specimen Calculations:

1. Diameter of the flywheel (D) is given by,

$$D = \frac{\text{Circumference of the fly wheel}}{\pi} = 14.8 \text{ cmts}$$

2. Angle 'θ' in degrees is given by,

$$\theta = \frac{S * 360}{\pi * D}$$

Where,

S = Arc length in mm

PRECAUTIONS:

- The ports opening are to be taken as the point when it just begins to open.
- The ports closure is taken as the point where the port closes completely.
- The flywheel is to be rotated in proper direction.

RESULT:

The following are found out and port timing diagram is drawn as shown with the following data:

- Angle at Transfer Port Open (IVO) - Before BDC = _____
- Angle at Transfer Port Close (IVC) - After BDC = _____
- Angle at Exhaust valve Open (EVO) - Before BDC = _____
- Angle at Exhaust valve Close (EVC) - After BDC = _____
- Port Timing diagram is drawn

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Experiment No. 03

Date:

PERFORMANCE TEST ON SINGLE CYLINDER

2 - STROKE PETROL ENGINE

AIM:

The experiment is conducted to

- a. To study and understand the performance characteristics of the engine, and
- b. To draw Performance curves and compare with standards.

EQUIPMENT & APPARATUS:

- 2-Stroke, Single Cylinder Petrol Engine with Rope Brake Dynamometer
- Tachometer
- Stop Watch

SPECIFICATIONS:

- Make : Bajaj
- Stroke : 66.7mm
- Bore : 70mm
- Capacity : 150cc
- Rated R.P.M : 3000rpm
- Out put : 2.2KW
- Fuel : Petrol
- Sp. Gr. Of petrol : 0.716
- Calorific Value of petrol : 43120 KJ/Kg
- Lubrication : 3% mixture of self mixing oil and petrol

Theory:

Petrol engine is an air cooled, single cylinder, Vertical, 2-stroke engine. The engine is kick started. The petrol engine is coupled through the gear box to a water cooled rope brake dynamometer to absorb the power produced. The speed ratio between the engine and brake drum is 5:1(Top gear engaged).

Fuel consumption is measured with a burette and a stop watch. A three-way cock, which regulates the flow of petrol from the tank to the engine.

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PROCEDURE:

1. Give the necessary electrical connections to the panel.
2. Check the lubricating oil level in the engine.
3. Check the fuel level in the tank.
4. Release the load if any on the dynamometer.
5. Open the three-way cock so that fuel flows to the engine.
6. Set the accelerator to the minimum condition.
7. Start the engine by cranking.(KICK START)
8. Allow to attain the steady state.
9. Load the engine by switching on the Load controller switches provided. (Each loading is incremental of 0.5kW)
10. Note the following readings for particular condition,
 - a. Engine Speed
 - b. Time taken for ___cc of petrol consumption
 - c. Water meter readings.
 - d. Manometer readings, in cms of water &
 - e. Temperatures at different locations.
11. Repeat the experiment for different loads and note down the above readings.
12. After the completion release the load (while doing so release the accelerator) and then switch of the engine by pressing the ignition cut – off switch and then turnoff the panel.

OBSERVATION:

S. No.	Speed	Loading	Manometer Reading			Time for 10 ml of fuel Consumption	Time for 5 Rev. of Energy Meter	SFC	Brake Power	Heat Input	Brake Thermal Efficiency	Volumetric Efficiency
1	1000											
2	1000											
3	1000											
4	1000											
5	1000											

Specimen Calculations:

1. Mass of fuel (m_f) is given by,

$$m_f = \frac{X_{cc} * \text{Specific Gravity of fuel}}{1000 * t} \text{ kg/sec}$$

Where,

Specific Gravity of Diesel is 0.716

X_{cc} is the volume of fuel consumed = 10ml

t is time taken in seconds

2. Heat Input is given by,

$$H.I = m_f * \text{Calorific Value of Diesel kW}$$

Where,

Calorific Value of Diesel = 43120 KJ/Kg

3. Engine Output Brake Power is given by,

$$\text{Engine Output BP} = \frac{n * 3600}{K * T * \eta_m} \text{ kW}$$

Where,

Where,

n = No. of revolutions of energy meter (Say 5)

K = Energy meter constant = 750 rev/kW - hr

T = time for 5 rev. of energy meter in seconds

η_m = efficiency of belt transmission = 80%

4. SFC (Specific Fuel Consumption) is given by,

$$SFC = \frac{m_f}{B.P} * 3600 \text{ kg/ kW - hr}$$

Where,

m_f = Mass of fuel

5. Brake Thermal Efficiency is given by,

$$\eta_{Brake} = \frac{3600 * 100}{SFC * C_V}$$

Where,

SFC = Specific Fuel Consumption

C_V = Calorific Value of Diesel = 43120 KJ/Kg

6. Volumetric Efficiency is given by,

$$\eta_{Volumetric} = \frac{Q_{Actual}}{Q_{Theoretical}} * 100$$

Where,

Q_{Actual} = Actual Discharge flowing through the rotating drum

$$Q_{Actual} = C_d * A * \sqrt{2g * H_{air}}$$

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Where,

$C_d = \text{Coefficient of Discharge} = 0.62$

$A = \text{Area of the orifice} = \frac{\pi}{4} * D^2 = \frac{\pi}{4} * 0.3^2 = 0.0706 \text{ m}^2$

$H_{\text{air}} = \text{Height of the liquid column raised in the manometer}$

$$H_{\text{air}} = \frac{1000(H_1 + H_2)}{1.2}$$

$Q_{\text{Theoretical}} = \text{Theoretical Discharge of water flowing through rotating drum}$

$$Q_{\text{Theoretical}} = \frac{\frac{\pi}{4} * D^2 * L * G_r * 0.5 * N}{60}$$

Where,

$D = \text{Bore diameter of the engine} = 0.057\text{m}$

$L = \text{Length of the Stroke} = 0.057\text{m}$

N is speed of the engine in rpm.

$G_r = \text{gear ratio}$

- 1st gear = 14.47:1
- 2nd gear = 10.28:1
- 3rd gear = 7.31:1
- 4th gear = 5.36:1

PRECAUTIONS

1. Do not run the engine if supply voltage is less than 180V
2. Do not run the engine without the supply of water.
3. Supply water free from dust to prevent blockage in rota meters, engine head and calorimeter.
4. Note that the range for water supply provided is an approximate standard values, however the user may select the operating range to his convenience not less than 3 & 2 LPM for engine and calorimeter respectively.
5. Always set the accelerator knob to the minimum condition and start the engine.
6. Switch off the ignition of AUXILLARY while doing in the engine arrangement.
7. Do not forget to give electrical earth and neutral connections correctly.
8. It is recommended to run the engine at 1000rpm otherwise the rotating parts and bearing of engine may run out.

Graphs:

Graphs to be plotted:

- 1) SFC v/s BP
- 2) η_{brake} v/s BP
- 3) η_{Volu} v/s BP

Result:

By following the sequence of operation, the single cylinder two stroke petrol engine is optimized at rated speed of 1000 rpm on the following data are identified to know the performance of given

Two – Stroke Petrol Engine

1. Average brake thermal efficiency =
2. Average volumetric efficiency =
3. Graphs are plotted as specified above

Experiment:4

Date:

Morse test on the two cylinder four stroke diesel engine.

AIM

To study and conduct Morse test on the multi cylinders four stroke diesel engine.

APPARATUS:

Two cylinder four stroke diesel engine
Stopwatch

THEORY:

Morse Test is used to find a close estimate of Indicated Power (IP) of a Multi cylinder Engine. In this test, the engine is coupled to a suitable dynamometer and the brake power is determined by running the engine at the required speed. The fuel flow in first cylinder is now cut off by closing the fuel injector of the first cylinder in the diesel engine.

As a result of cutting out the first cylinder, the engine speed will drop. Load on the engine is now removed so that the original speed is attained. The brake power under this load is determined and recorded (BP1). The first cylinder operation is restricted normal and the second cylinder is fuel injector is cut-out. The engine speed will again vary. By adjusting the load on the engine, speed brought to original speed and the new BP is recorded (BP2).

PROCEDURE:

Start set up and run the engine at no load for some time for warming up the engine. Gradually increase the load on the engine by loading it.

Increase the engine throttle to any desired position and simultaneously load the engine to obtain desired speed for which frictional power is to be calculated.

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Wait for few minutes till steady state is achieved, note engine speed and load.

Cut off the fuel flow in the first cylinder. The engine speed will decrease, at this state decrease the load and bring the engine speed to the original state.

Wait for steady state and tabulate the readings.

Repeat the procedure for the second cylinder and tabulate the readings.

OBSERVATIONS TABLE:

Sl. No.	Cylinder Condition	Engine Speed N (rpm)	Load W (kgs)	Brake Power r (HP)	Indicated Power (IP)
1.	All cylinders are firing			(BP) =	(IP)
2.	First cylinder is cut-off			(BP1) =	(IP1)
3.	Second cylinder is cut-off			(BP2) =	(IP2)

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CALCULATIONS:

1. Total Brake Power (BP), when all Cylinders are firing.

$$BP = \frac{2\pi NT}{4500} \text{ HP}$$

2. Brake Power (BP1), when first Cylinder is cut-off.

$$BP1 = \frac{2\pi NT_1}{4500} \text{ HP}$$

3. Brake Power (BP2), when second Cylinder is cut-off.

$$BP2 = \frac{2\pi NT_2}{4500} \text{ HP}$$

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4. Indicated Power (IP), when first Cylinder is not firing.

$$IP1 = (BP) - (BP1)$$

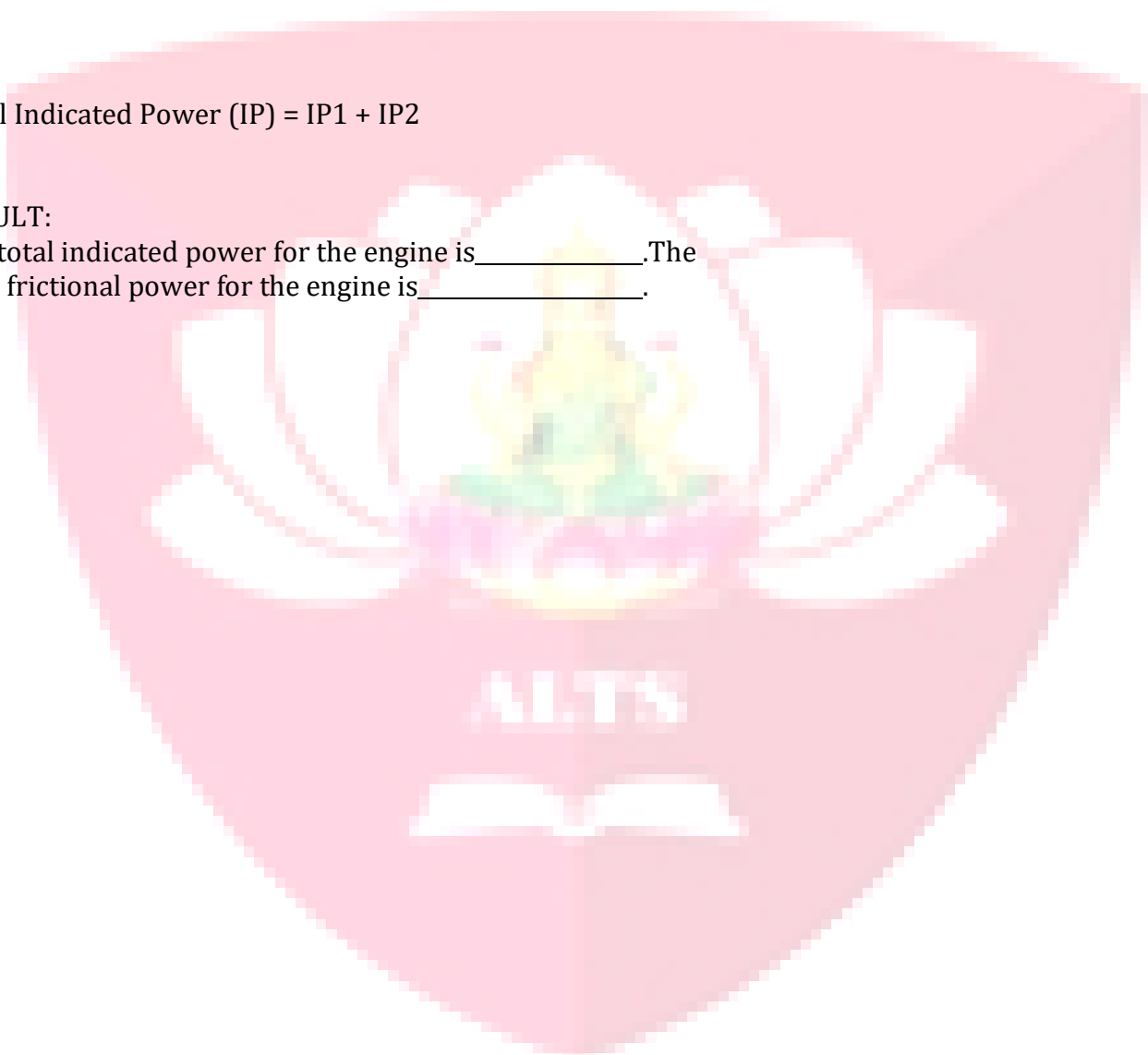
Similarly, when second is not firing

$$IP2 = (BP) - (BP2)$$

Total Indicated Power (IP) = $IP1 + IP2$

RESULT:

The total indicated power for the engine is _____. The total frictional power for the engine is _____.



I.C. Engine Performance Test Single Cylinder 4 Stroke Diesel Engine

AIM:

The experiment is conducted to

- a. To study and understand the performance characteristics of the engine.
- b. To draw Performance curves and compare with standards.

Apparatus:

- I.C. Engine - Single Cylinder 4 Stroke Diesel Engine Test Rig – Mechanical Loading
- Stop Watch
- Tachometer
- Manometer

SPECIFICATIONS:

- Make : Kirloskar model AVI
- Stroke, L : 110 mm
- Bore, D : 80 mm
- Swept volume, V : 256 cm³
- Rated R.P.M : 1500rpm
- Out put : 3.7KW (5 H.P)
- Compression ratio, CR : 4.67:1
- Orifice Diameter : 30mm
- Fuel : Diesel
- Density of Diesel : 0.827 gm / ml
- Calorific Value of Diesel : 44631.96 KJ / kg
- Brake drum diameter : 0.3m
- Rope diameter : 0.015m
- Equivalent diameter : 0.315 m
- Loading : Electrical, Air heater connected to AC Generator
- Cooling : Air cooling

Theory:

The Test Rig consists of Four-Stroke Petrol Engine (Air Cooled) to be tested for performance is coupled to AC Generator .To facilitate the change in compression ratio, an auxiliary head-piston assembly above the main head has been provided.

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The auxiliary piston is operated up-down by hand wheel-screw rod assembly to fix the required compression ratio. When the piston is in the bottom most position, the compression ratio is at its maximum value, and in the top most position it is at minimum value of 2s.

The minimum clearance volume is 35 cc when the piston it is at its bottom most position. The charge from this initial volume of clearance is determined by the displacement of the piston and thus used for calculation of the compression ratio.

The hand wheel which operates the screw holding the auxiliary piston is provided with holes circumferentially along the locking plate. The bolts used for locking the movement of screw are loosened and the hand wheel is operated. A scale with the compression ratio directly marked is provided for indicating this.

After adjusting to the required compression ratio, all the bolts are tightened well before conducting experiment. The rate of fuel Consumption is measured by using Volumetric Pipette. Air Flow is measured by Manometer, connected to air box.

The different electrical loadings are achieved by loading the Electrical generator in steps which is connected to the Air Heaters (Resistance Load). The engine speed & AC Alternator speed are measured by electronic digital counter.

Temperatures at air inlet and engine exhaust gas are measured by electronic digital temperature indicator with thermocouple. The whole instrumentation is mounted on a self-contained unit ready for operation.

PROCEDURE:

1. Give the necessary electrical connections to the panel.
2. Loosen the locking bolt of the auxiliary piston screw rod assembly
3. Rotate the hand wheel and bring the indicator to the required compression ratio
4. Lock the screw rod assembly before conducting the experiment for the compression ratio selected.
5. Open the 3-way cock. So that fuel flows into the engine.
6. Supply the cooling water to engine head.
7. Start the engine and allow it to run on no load condition for few minutes.
8. Apply the load on the engine by switching ON the heater switch which is provided on the control panel loading the AC generator by switching
9. Allow the engine to run at this load for few minutes.
10. Note the following readings.

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- a) Engine Speed
- b) Energy meter
- c) Manometer
- d) Time for 10cc of fuel consumption

11. Repeat the procedures 8 & 9 at different loads.
12. Stop the engine after removing load on the engine
13. Change the compression ratio and repeat the above procedure.

OBSERVATION:

S. No.	Speed	Loading	Manometer Reading			Time for 10 ml of fuel Consumption	Time for 5 Rev. of Energy Meter	SFC	Brake Power	Heat Input	Brake Thermal Efficiency	Volumetric Efficiency
1	1000	0										
2	1000	1										
3	1000	1.5										
4	1000	2										
5	1000	2.5										

Specimen Calculations:

1. Mass of fuel (m_f) is given by,

$$m_f = \frac{X_{cc} * \text{Specific Gravity of fuel}}{1000 * t} \text{ kg/sec}$$

Where,

Specific Gravity of Diesel is 0.827

Xcc is the volume of fuel consumed = 10ml

t is time taken in seconds

2. Heat Input is given by,

$$H.I = m_f * \text{Calorific Value of Diesel kW}$$

Where,

Calorific Value of Diesel = 44631.96 KJ/Kg

3. Engine Output Brake Power is given by,

$$\text{Engine Output BP} = \frac{2\pi * N * T}{60 * 1000} \text{ kW}$$

Where,

N is speed in rpm

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T = Torque = F x r x 9.81 N - m
 r = Radius of the Drum = 0.15m

4. SFC (Specific Fuel Consumption) is given by,

$$SFC = \frac{m_f}{B.P} * 3600 \text{ kg/ kW} - \eta r$$

Where,

m_f = Mass of fuel

5. Brake Thermal Efficiency is given by,

$$\eta_{Brake} = \frac{3600 * 100}{SFC * C_v}$$

Where,

SFC = Specific Fuel Consumption

C_v = Calorific Value of Diesel = 44631.96 KJ/Kg

6. Volumetric Efficiency is given by,

$$\eta_{Volumetric} = \frac{Q_{Actual}}{Q_{Theoretical}} * 100$$

Where,

Q_{Actual} = Actual Discharge flowing through the rotating drum

$$Q_{Actual} = C_d * A * \sqrt{2g * H_{air}}$$

Where,

C_d = Coefficient of Discharge = 0.62

A = Area of the orifice = $\frac{\pi}{4} * D^2 = \frac{\pi}{4} * 0.3^2 = 0.0706 \text{ m}^2$

H_{air} = Height of the liquid column raised in the manometer

$$H_{air} = \frac{1000(H_1 + H_2)}{1.2}$$

$Q_{Theoretical}$ = Theoretical Discharge of water flowing through rotating drum

$$Q_{Theoretical} = \frac{\frac{\pi}{4} * D^2 * L * N}{120}$$

Where,

D = Bore diameter of the engine = 0.08m

L = Length of the Stroke = 0.011m

N is speed of the engine in rpm.

7. Mechanical Efficiency :

$$\eta_{Mechanical} = \frac{Break \ Power}{Indicated \ Power} = \frac{Break \ Power}{Frictional \ Power + Break \ Power}$$

Where,

F.P. = Frictional power for Four Stroke Diesel Engine - Electrical Loading = 1.5 kW

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Graphs:

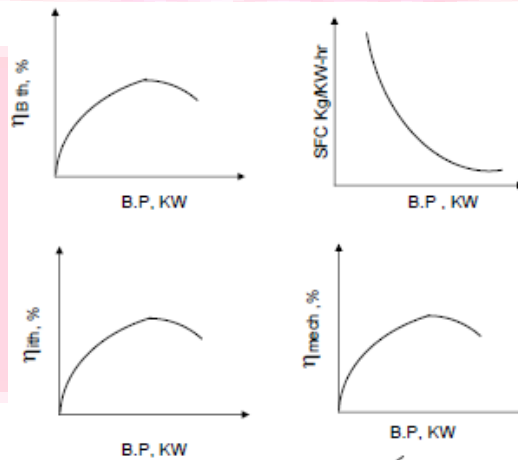
Graphs to be plotted:

- 1) SFC v/s BP
- 2) η_{brake} v/s BP
- 3) η_{mech} v/s BP
- 4) η_{Volu} v/s BP

PRECAUTIONS:

1. Before starting the engine check all the systems such as cooling, lubrication and fuel system
2. Ensure oil level is maintained in the engine upto recommended level always. Never run the engine with insufficient oil.
3. Never run the engine with insufficient engine cooling water and exhaust gas calorimeter cooling water.
4. For stopping the engine, load on the engine should be removed
5. Don't increase the compression ratio beyond 8.0
6. Do not forget to give electrical earth and neutral connections correctly.
7. Do not run the engine if supply voltage is less than 180V
8. Do not run the engine without the supply of water.

Model graphs:



Result:

By following the sequence of operation, the single cylinder four stroke diesel engine is optimized at rated speed of 1500 rpm on the following data are identified to know the performance of given 4

–stroke Diesel Engine: Electrical Loading

1. Average brake thermal efficiency =

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2. Average volumetric efficiency =
3. Average mechanical efficiency =
4. Graphs are plotted as specified above.



APPLIED THERMODYNAMICS LABORATORY MANUAL

EXPERIMENT-6 TO DISASSEMBLE AND ASSEMBLE PETROL ENGINE

AIM: To disassemble and assemble a given petrol engine.

Introduction: Due to use of engine continuously over period of time they may develop certain troubles. Such as loss of efficiency noise irrational, fluctuations manufacturing of fuel pump injector. As such there will be necessity of strip of all parts of the engine inspect then for visual detects provide packing and scaling when ever required for this purpose Disassembling and assembling of a petrol engine is done in a certain manner or correct sequence.

PROCEDURE: The following procedure is to be followed while disassembling and assembling of a four-stroke cylinder petrol engine.

- a) Study of the engine.
- b) Plan the method for disassembling and keep the tools ready.
- c) Remove the rocker armies boxes
- d) Remove the rocker armies and screw's to displace the covering plate on cylinder head.
- e) Remove injector pipe end disconnect the injector.
- f) Remove both the exhaust and inlet
- g) Remove the push rod cover.
- h) Remove the petrol tank
- i) Remove fly wheel and fly wheel housing
- j) Remove fuel pump and curb wetter
- k) Remove the cylinder block
- l) Remove connecting rod big ends and bearing
- m) Remove side cover's
- n) Remove the can shaft from the bearing.
- o) Draw out all the lubricating oil from crank case

p) Remove the oil filter.

The following procedure is to be followed broadly in the gives sequence for assembling the disassembled petrol engine

- 1) After proper cleaning and checking of all parts assembling is carried out
- 2) Position the piston along with rings to the small end of connecting rod, insert grudgepin for fixing the piston to small end of the connecting rod.
- 3) Position the crankshaft into the bearing in the proper way
- 4) Fix the side covers and tighten properly.
- 5) Position the cylinder block and fix it in a proper way
- 6) Fix the fuel pump and distributor
- 7) Position the fly wheel housing and fix the fly wheel correctly.
- 8) Fix both the inlet and the exhaust manifold.
- 9) Place the cylinder head block properly and fix the nut's properly.
- 10) Position the rocker arm and fix them correctly.
- 11) Tighten all the blocks with the help of nuts to make the engine fit.

PRECAUTIONS: All the nuts and bolts removed during the disassembling should be placed carefully. While dealing with rocker arms and crank shaft care must be taken. Use only the tools while disassembling and assembling.

RESULT:

Assembling and disassembling of four-stroke four-cylinder petrol engine is done.

EXPERIMENT -8

AIM: The experiment is conducted at various pressures to

- a. Determine the Volumetric efficiency.
- b. Determine the Isothermal efficiency.

PROCEDURE:

1. Check the necessary electrical connections and also for the direction of the motor.
2. Check the lubricating oil level in the compressor.
3. Start the compressor by switching on the motor.

4. The slow increase of the pressure inside the air reservoir is observed.
5. Maintain the required pressure by slowly operating the discharge valve (open/close). (Note there may be slight variations in the pressure readings since it is a dynamic process and the reservoir will be filled continuously till the cut-off.)
6. Now note down the following readings in the respective units,
Speed of the compressor. Manometer readings.
Delivery pressure. Temperatures.
Energy meter reading.
7. Repeat the experiment for different delivery pressures.
8. Once the set of readings are taken switch off the compressor.
9. The air stored in the tank is discharged. Be careful while doing so, because the compressed air passing through the small area also acts as a air jet which may damage you or your surroundings.
10. Repeat the above two steps after every experiment.

Volumetric Efficiency of a Reciprocating Air Compressor

OBSERVATIONS:

Sl. No.	Compressor Speed, rpm	Delivery Pressure, 'P' kg/cm ²	Manometer Reading			Time for 'n' revolutions of energy meter, 'T' sec
			h ₁ cm	h ₂ cm	h _w = (h ₁ ~h ₂)	

CALCULATIONS:

1. Air head causing flow, h_a

$$\text{Manometer Head } H_a = (h_1 - h_2) \times \frac{\rho_w}{\rho_a} \text{ m}$$

$$\rho_w = 1000 \text{ kg/m}^3$$

$$\rho_a = 1.293 \text{ kg/m}^3, h_1 \text{ and } h_2 \text{ in m}$$

2. Actual vol. of air compressed at RTP,

Where,

h_a is air head causing the flow in **m** of air.

C_d = coefficient of discharge of orifice = 0.62

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

Where,

d = diameter of orifice = 0.02m

3. Theoretical volume of air compressed Q_{th} ,

Where,

D is the diameter of the LP cylinder = 0.07m.

L is Stroke Length = 0.085m

N is speed of the compressor in rpm

4. Input Power, **IP**

$$3600 * n * \eta_m / (K * T) \dots\dots\dots kW$$

Where,

n = No. of revolutions of energy meter (Say 5)

K = Energy meter constant revs/kW-hr

T = time for 5 rev. of energy meter in seconds

η_m = efficiency of belt transmission = 75%

5. Isothermal Work done, WD

$$WD = \rho_a \times Q_a \ln r \text{ kW}$$

Where,

ρ_a = is the density of the air = 1.293 kg/m³
 Q_a = Actual volume of air compressed.

r = Compression ratio

r = $\frac{\text{Delivery gauge pressure} + \text{Atmospheric pressure}}{\text{Atmospheric pressure}}$

Where Atmospheric pressure = 101.325 kPa

NOTE: To convert delivery pressure from kg/cm² to kPa multiply by 98.1

6. Volumetric efficiency, η_{vol}

$$\eta_{vol} = Q_a / Q_{th} \times 100$$

7. Isothermal efficiency, η_{iso}

$$\eta_{iso} = \frac{\text{Isothermal work done}}{IP} \times 100$$

TABULATIONS:

S. No	Head of Air h_a, m	Actual volume of air compressed $Q_a, m^3/s$	Theoretical vol of air compressed $Q_{th}, m^3/s$	Isothermal work done Kw	Iso thermal efficiency $\eta_{iso}, \%$	Volumetric Efficiency $\eta_{vol}, \%$

GRAPHS TO BE PLOTTED:

1. Delivery Pressure vs. η_{vol}
2. Delivery Pressure vs. η_{iso}

PRECAUTIONS:

1. Do not run the blower if supply voltage is less than 380V
2. Check the direction of the motor, if the motor runs in opposite direction change the phase line of the motor to run in appropriate direction.
3. Do not forget to give electrical earth and neutral connections correctly.

RESULT:

EXPERIMENT No: 9

AIM: Determination of Nozzle characteristics

Nozzles and Diffusers

A *nozzle* is a device that *increases the velocity* of a fluid at the expense of pressure. A *diffuser* is a device that *increases the pressure* of a fluid by slowing it down.

The cross sectional area of a nozzle decreases in the flow direction for subsonic flows and increase for supersonic flows.

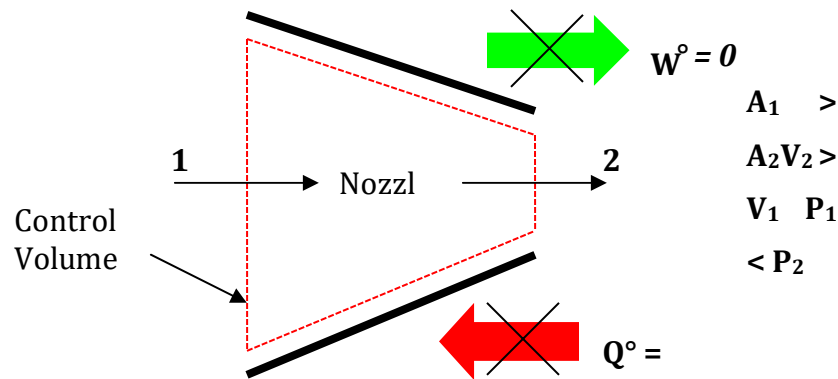


Fig. 9: T-elbow is a mixing chamber.

Common assumptions for mixing chamber: $Q^\circ = 0$, $W^\circ = 0$, $\Delta PE = \Delta KE = 0$.

Fig. 4: Schematic of nozzle. For a nozzle, common assumptions and idealizations are: $Q^\circ = 0$, no time for heat transfer, due to high velocity

$W^\circ = 0$, nozzles include no shaft or electric resistance wires $\Delta PE = 0$, no change in fluid elevation.

Mass equation for nozzles becomes:

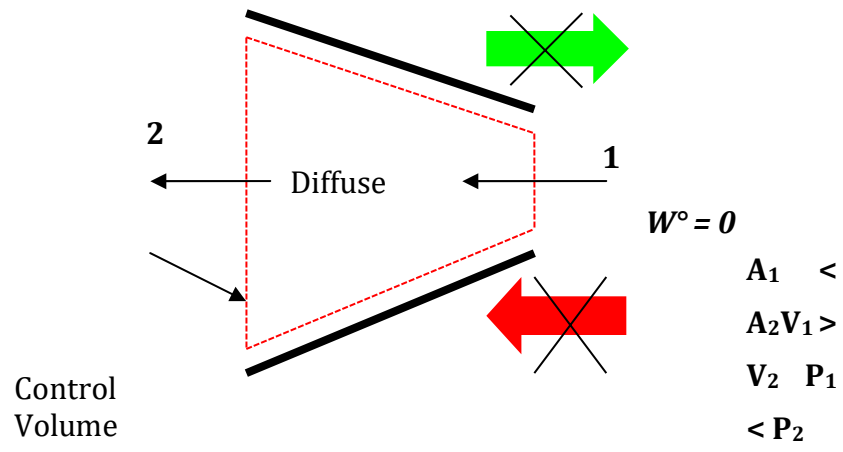
$$m^\circ_1 = m^\circ_2 \quad \text{or} \quad \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

Energy balance:

$$Q^\circ - W^\circ = m^\circ_1 \theta_1 - m^\circ_2 \theta_2$$

$$(h + V^2 / 2)_{\text{at inlet}} = (h + V^2 / 2)_{\text{at exit}}$$

Diffusers are exactly the same device as nozzles; the only difference is the direction of the flow. Thus, all equations derived for nozzles hold for diffusers.



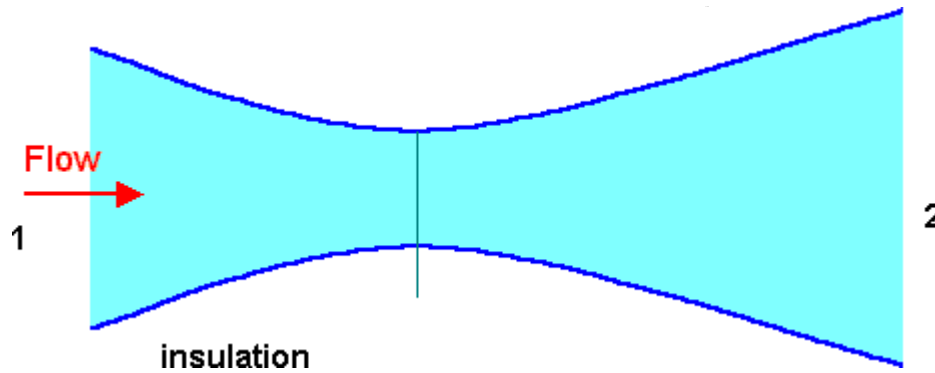


Fig. 6: Converging-diverging nozzle.

Turbines and Compressors

In steam, gas, or hydroelectric power plants, the device that derives the electric generator is turbine. The work of turbine is positive since it is done by the fluid.

Compressors, pumps, and fans are devices used to increase the pressure of the fluid. Work is supplied to these devices, thus the work term is negative.

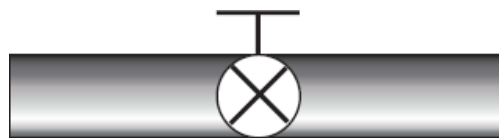
Common assumptions for turbines and compressors:

$$Q^\circ = 0.$$

$$\Delta PE = \Delta KE = 0.$$

Throttling Valves

Any kind of flow restricting devices that causes a significant pressure drop in the fluid is called throttling valve.



a) an adjustable valve



b) a porous plug



c) a capillary tube

Fig. 8: Three kinds of throttling valves.

The pressure drop in fluid is often accompanied with a temperature drop in fluids. The magnitude of this temperature is governed by a property called the *Joule-Thomson coefficient*.

Common assumptions for throttling valves: $Q^\circ = 0$

$$= 0$$

$$W^\circ = 0$$

$$\Delta PE = \Delta KE = 0.$$

The conservation of energy becomes:

$$h_2 = h_1$$

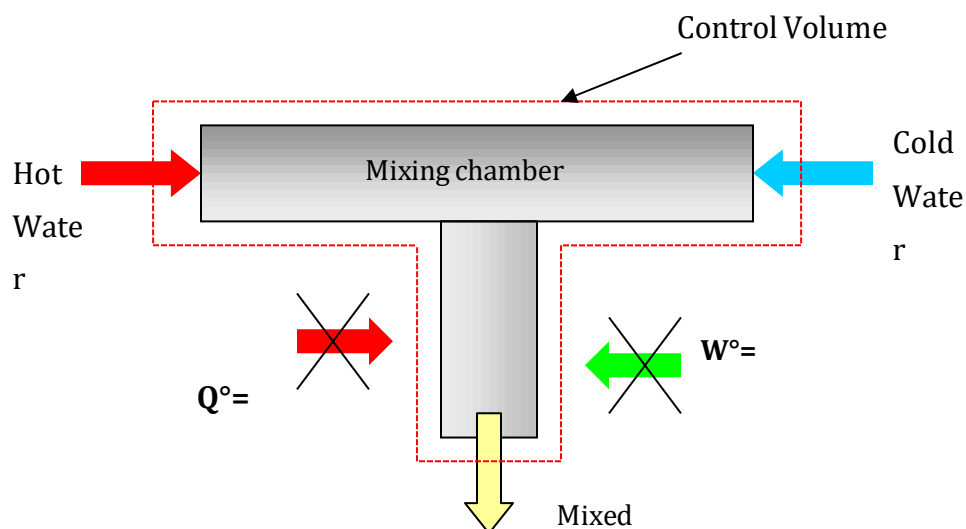
$$u_1 + P_1 v_1 = u_2 + P_2 v_2$$

The flow energy increases during the process ($P_2 v_2 > P_1 v_1$), and it is done at the expense of the internal energy. Thus, internal energy decreases, which is usually accompanied by a drop in temperature.

For ideal gases $h = h(T)$ and since h remains constant the temperature has to remain constant too.

Mixture Chambers (Direct Contact Heat Exchangers)

Mixture chambers are used to mix two streams of fluids. Based on mass principle, the sum of incoming flow equals to sum of leaving fluid.



The conservation of energy becomes:

$$\Sigma(m \circ h)_{inlet} = \Sigma(m \circ h)_{outlet}$$

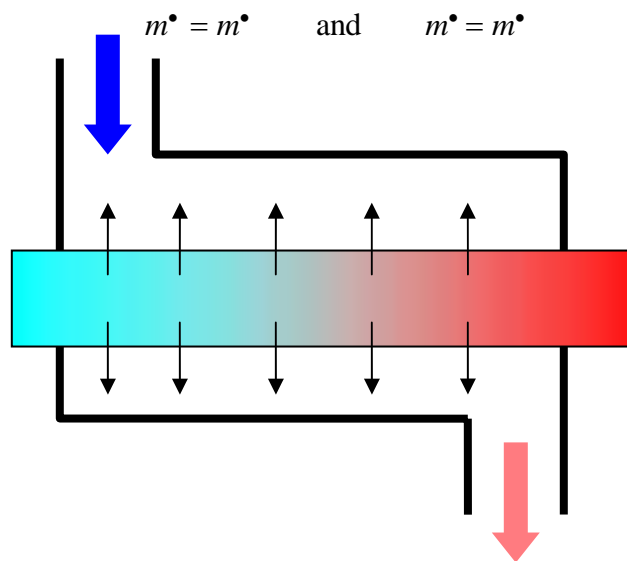
Heat Exchangers

Heat exchangers are devices where two moving fluid streams exchange heat without mixing. Common assumptions for heat exchangers:

$$W \circ = 0$$

$$\Delta PE = \Delta KE = 0.$$

$Q \circ$ could be different depending on the selected CV, see the next example. The mass and energy balance become:



Experiment No 10

Simple Vapour Compression Refrigeration System

AIM: Study and evaluate the performance simple vapor Compression Refrigeration System (VCRS) and its components.

OBJECTIVES:

1. To study various Components of Vapour Compression Refrigeration
2. System (VCRS) like Compressor, Condenser, Evaporator and Expansion device.
3. To study effect of sub cooling and superheating on the performance of VCRS.
4. To Study the effect of varying the suction and discharge pressure on the performance of VCRS.

THEORY:

Mainly there are four components in VCRS.

(1) Evaporator (2) Compressor (3) Condenser (4) Expansion Device.

First the refrigerant is compressed adiabatically in the compressor. The pressure and temperature of the refrigerant will increase. Then refrigerant will enter in the Condenser. Heat will be rejected from the refrigerant to the atmosphere in Condenser at constant pressure. Then, the refrigerant will enter in expansion device where expansion takes place which result in reduction of temperature and pressure of refrigerant. This low temperature refrigerant will enter into evaporator and by its evaporation cooling will be produced at constant pressure. The heat absorbed in evaporator is termed as Refrigeration effect. This low temperature refrigerant vapor enters in compressor and cycle is repeated.

QUESTIONS:

1. Define Refrigeration and Air-conditioning. State the application of refrigeration.
2. Explain with neat sketch the working principle of simple Vapor Compression Refrigeration System.
3. What is C.O.P of a refrigeration system?
4. Explain the effect of Sub-cooling and Super-heating of on the performance of a simple VCRS.
5. Explain the effect of varying suction pressure and discharge pressure on the performance of VCR with p-h and T-S diagram.
6. Draw and explain actual vapor compression refrigeration cycle.
7. The following results were obtained in a test conducted on vapor-compression refrigeration system. Evaporator temperature = 28°C, Condenser pressure = 2.8 bar Refrigerant entering the condenser = 3°C superheat

Refrigerant leaving the condenser = 12°C

Draw up heat balance sheet and calculate C.O.P. Take the following properties for refrigerant

Saturation Temp °C	Pressure bar	Enthalpy kJ/kg		Entropy kJ/kg Kvapour	Sp. Heat kJ/kg K	
		liquid	vapour		liquid	vapour

8. A R-12 vapour compression system has saturated suction temp of -5°C and saturated discharge temp of 40°C. calculate (1) mass flow rate /ton of refrigeration (2) theoretical piston displacement /ton of refrigeration (3) theoretical power /ton of refrigeration (4) COP with (a) dry compression (b) wet compression. Find the system performance when capacity is 15TR.
9. A food storage locker required a refrigeration system of a 2400 kJ/min capacity. The evaporator temp is -10°C and a condenser temp is +30°C. The refrigerant used is R12. The refrigerant is sub cooled by 6°C before entering the expansion valve. The vapour is superheated by 7°C before leaving the evaporator coil. The compression of the refrigerant is isentropic. The refrigerant compressor is 2 cylinder, single acting L/D=1.25 and it operates at 1000 rpm. The properties of R12 is as under:

Saturation Temp °C	Absolute Pressure bar	Sp. volume m ³ /kg v _g	Enthalpy kJ/kg		Entropy kJ/kg K		Sp. Heat kJ/kg K	
			liquid	Vapour	liquid	vapour	liquid	vapour

CONCLUSION: Evaluated the performance simple vapor Compression Refrigeration System (VCRS) and its components.

Experiment No 11

Performance of Air conditioning system

THEORY

Air conditioning is making the environment conditions suitable for various applications, like to produce comfortable conditions at home, or to make more complete control of manufacturing processes in industries etc. a complete air conditioning system cleans the air, cools in summer and heats in winter, humidifies in winter and dehumidifies in summer and circulates it through the space where it is required. All the systems may not be equipped with all these controls. This unit is designed to study the basic processes of heating, cooling dehumidification and humidification.

THE APPARATUS

The unit consists of a duct, in which air flow is generated by an axial flow fan. A cooling coil, air heaters, and a steam injector are fitted in the duct. Adjustable flappers are provided in duct to control the air flow. At reduced flow rates of air, cooling coil can be used as dehumidifier. The condensing unit and steam generator is located below the air flow duct. The hermetic compressor compresses the refrigerant vapour and sends it to condenser, where it is liquefied. The liquid refrigerant is throttled by expansion valve to low pressure and temperature. This low temperature refrigerant goes to evaporator where it boils by collecting heat. The low pressure refrigerant vapour coming from the evaporator is sucked by the compressor and again circulated through the system.

A steam generator with electrical heater is provided below the duct, which connected to steam injector in the duct. The steam injection is controlled by a valve. Various measurements are provided so different processes of air conditioning can be studied.

SPECIFICATIONS

Compressor – 0.6 ton (approx.) capacity, hermetically sealed, using refrigerant R-22 (Monochlorodifluoromethane).

Finned tube condenser with fan. Capillary tube.

Finned tube direct expansion evaporator fitted in a duct of cross section of 250 x 250 mm. Fan to generate the air flow over the evaporator coil.

Steam generator with electrical heater and steam injector. Heaters in the duct.

Measurement and controls.

Thermometers for cooling cycle and dry/wet bulb air temperatures.

Energy meter's for compressor and heater input-02 nos.

Pressure gauges to measure condensing and evaporating pressures.High/low pressure output.

Necessary switches.

Flow control flappers in the duct.

TERMINOLOGY

Dry air- It is a mixture of constituent gases which comprise the atmospheric air, excluding water vapour.

Moist air- It is the mixture of dry air and water vapour. Generally atmospheric air is moist air.Humidity – Water vapour that is mixed with atmospheric air is called humidity.

Specific Humidity- It is mass of water vapour in moist air, expresses in Kg / Kg of dry air.

Absolute Humidity – It is mass of water vapour contained in a volume of air and is expressed in grams per m³ of air.

Relative Humidity – It is the ratio of weight of water vapour contained in air at given temperature in a given space to the maximum amount (mass) of water vapour that the air would contain at the same temperature and volume, when fully saturated.

Saturated Vapour – When air – water vapour mixture contains maximum amount of water vapour it can hold, it is called saturated. When temperature of mixture is above saturation temperature, the vapour is supersaturated.

Dalton's Law – In a mechanical mixture of gases, total pressure of the mixture is the sum of partial pressures of gases that each gas would exert when occupied the same volume at the same temperature as that of the mixture.

Dry Bulb Temperature – It is the temperature indicated by ordinary thermometer.

Wet Bulb Temperature – It is temperature indicated by a thermometer whose bulb is covered by a wet wick. The difference between Dry Bulb Temperature and Wet Bulb Temperature is called WET BULB DEPRESSION.

EXPERIMENTAL PROCEDURE

(A) COOLING OF AIR

Fill up water in the wells of DB / WB thermometers.

Adjust the flapper opening to a specific degree. Say 10°C

Put ON main switch. Start air flow through the duct, start the condenser fan and then start the compressor.

Wait till steady temperatures are reached and note down the observations.

Repeat the procedure by changing the air flow.

(B) HEATING OF AIR

Put ON the main switch and start air flow through the duct. Put ON the heaters, as required.

Wait till steady state conditions are reached note down the readings.

Repeat the procedure at different air flow rates and changing the heat input.

(C) HUMIDIFICATION OF AIR

- (1) Fill up sufficient water in steam generator, and start the steam heater.
- (2) After some time, steam will be generated. Now start air flow through the duct, and slightly open the steam control valve so that steam will be injected in the stream of air.
- (3) Note down the readings.

(D) DEHUMIDIFICATION OF AIR

- (1) Start the air flow in the duct. Reduce the flow by partially closing the flap (close the flappers to around half opening.)
- (2) Start the condenser fan and then start the compressor. Cooling coil now works as dehumidifier. Condensed water will start collecting in collecting tray.
- (3) Once steady temperatures are reached, drain all the condensed water. Then again start collecting the condensate.
- (4) Collect the condensate for a period of 15 minutes.
- (5) Note down the temperatures.
- (6) Repeat the procedure by changing air flow.

OBSERVATIONS

(A) COOLING OF AIR

Sr No	Inlet °C		Outlet °C		Flapper	Time for 10 rev. of compressor energy meter	Flow (LPH)
	DBT	WBT	DBT	WBT			

COOLING CYCLE OBSERVATIONS

TEMPERATURES

- (a) Condenser Inlet t_{ci} = °C
(b) Condenser Outlet t_{co} = °C
(c) Evaporator Inlet t_{ei} = °C
(d) Evaporator Outlet t_{eo} = °C

PRESSURES

- (a) Condensing pressure = kg / cm²
(b) Evaporating pressure = kg / cm²
(c) Flapper opening angle = °

(B) HEATING OF AIR

Sr No	Air inlet °C		Air outlet °C		Flapper	Time for 10 rev. of compressor energy meter
	DBT	WBT	DBT	WBT		

(C) HUMIDIFICATION OF AIR

Sr No	Air inlet °C		Air outlet °C		Flapper opening angle
	DBT	WBT	DBT	WBT	

(D) DEHUMIDIFICATION OF AIR

Sr No	Air inlet °C		Air outlet °C		Flapper opening angle	Condensate collected in 15 min
	DBT	WBT	DBT	WBT		

CALCULATION:

COOLING OF AIR

Inlet - DBT = _____ °C, WBT = _____ °C

Therefore, from table of Dry / Wet Bulb Temperatures, Relative humidity,

RH = _____ %

$$\text{Now, } RH = \frac{P_w}{P_{SAT}} \times 100$$

Where, P_w = Partial pressure of water vapour, Kg / cm²
 P_{sat} = Partial pressure of water vapour
 At saturation at DBT (to be taken from chart)

$$\therefore P_w = \frac{RH \times P_{sat}}{100} \quad \text{Kg / cm}^2$$

Now,

$$W = \frac{0.623 \times P_w}{(P - P_w)}$$

Where, W = weight of moisture Kg/Kg of dry air
 P = Atmospheric pressure Kg / cm²

(1) TOTAL ENTHALPY OF DRY AIR = $H_t = h_a + h_s + h_l + h_{sh}$

Where, h_a = Enthalpy of dry air = 1 x (DBT) KJ / Kg

h_s = Sensible heat of water vapour (up to WBT) = 4.2 x w x

(WBT) h_l = Latent heat of evaporation of water vapour (at wbt) =

$w \times l$

(l is taken from chart)

h_{sh} = Superheat of water vapour (from WBT to DBT)

= $w \times 1.9 \times (\text{DBT} - \text{WBT})$

Thus, calculate total heat of air at inlet and outlet ie, h_{ti} and h_{to} respectively. (2) AIR FLOW

(See table-2, showing air velocity ' V_a ' at a corresponding flapper opening)

Cross sectional area of duct 0.0529 m²

$$\text{Density of air, } \rho_a = \frac{1.293 \times 273}{273 + DBT_{out}}$$

So, mass flow rate of air

$$m_a = (0.0529 - 0.0188) \times V_a \times \rho_a \times 3600 \quad \text{Kg/hr}$$

(3) HEAT RECOVERED BY COOLING COIL

$$H = m_a \cdot (h_{ti} - h_{to}) \quad \text{Kg/hr}$$

(4) COOLING CYCLE PERFORMANCE

(i) Evaporating Pressure, $P_{eg} = \text{_____ kg / cm}^2$

ab

so absolute evaporating pressure, $P_{ea} = P_{eg} + 1.033 \text{ kg / cm}^2$ ab

(ii) Condensing Pressure, $P_{cg} = \text{_____ kg / cm}^2$ ab

so Absolute Condensing pressure, $P_{ca} = P_{cg} + 1.033 \text{ kg / cm}^2$ ab

(iii) From the temperatures, plot the cycle on P-H chart and find out enthalpy values.

$$H_{ci} = \text{_____Kj/Kg}$$

$$H_{co} = H_{ei} = \text{_____Kj/Kg}$$

$$H_{eo} = \text{_____Kj/Kg}$$

(vi) Refrigerating effect = $H_{eo} - H_{ei} = \text{_____Kj/Kg}$

(v) Compressor work = $H_{ci} - H_{eo} = \text{_____Kj/Kg}$

(vi) COP theo = $(H_{eo} - H_{ei}) / (H_{ci} - H_{eo})$

(vii) If time required for 10 rev of compressor energy meter is t_{com} sec. Compressor work,

$$C_w = \frac{3600 \times 10}{t_{com} \times EMCc} \text{ Kw}$$

Where, EMCc = Compressor energy meter constant = 3200 imp/kwh

(viii) COP act = H / C_w

(B) HEATING OF AIR

In a similar manner to cooling cycle, calculate heat gained by air $H = m_a (h_{ti} - h_{to})$ Kj/hr

(C) HUMIDIFICATION OF AIR

At inlet conditions, DB = _____ °C, WB = _____ °C, So RH_i = _____ %

At outlet conditions, DB = _____ °C, WB = _____ °C, So RH_o = _____ %

Increment of relative humidity = $RH_o - RH_i$

(D) DEHUMIDIFICATION OF AIR

At inlet conditions, DB = °C, WB = °C, So RH = _____ % So W_i = _____ Kg/Kg of air

At outlet conditions, DB = °C, WB = °C, So RH = _____ % So W_o = _____ Kg/Kg of

air Mass flow rate of air = m_a Kg/hr

Moisture removed within 15

minutes $m_a = (W_i - W_o) \times 15 / 60$

Kg/hr

Compare this with actual amount of condensate collected.

Actually, in large capacity year around air conditioning plants, instead of using these Processes individually a combination of processes is also used. Like dehumidification with heating in summer, or humidification with heating in winter. Equipment used for various processes depend upon the resources available, system requirements and accuracy and economy of comfort desired.

Table - 1

THERMODYNAMIC PROPERTIES OF R - 22

TEMP °C	SPECIFIC VOLUME m ³ / kg	
	Sat. liquid	Sat. vapour
-10	0.00075876	0.0653399
-5	0.00076831	0.0553394
0	0.00077834	0.0471354
4	0.00078673	0.0416124
8	0.00079549	0.0368493
12	0.00080465	0.0327239
16	0.00081424	0.0291361

20	0.00082431	0.0260032
24	0.00083491	0.0232572
26	0.00084043	0.0220111
28	0.00084610	0.0208411
30	0.00085193	0.0197417
32	0.00085793	0.0187076
34	0.00086412	0.0177341
36	0.00087051	0.0168168
38	0.00087710	0.0159517
40	0.00088394	0.0151351

Table-2

FLAPPER CLOSING (DEGREES)	AIR VELOCITY (m/s)
0 (fully open)	5.0
10	1.5
20	2.7
30	3.2
40	3.6
60	4.3
70	4.4
80	4.8

CONCLUSION:

EXPERIMENT No: 12

A) Trial On Mechanical Heat

PumpAim: To Study Heat pump and Calculate its COP

Prior Knowledge:

Basic concepts of Heat Pump and various equipments used in testing rig.

Use of Mechanical heat pump in Refrigeration.

Introduction:Now a days, energy conservation is becoming very important. Engineers have started Use of heat pump system for commercial and industrial buildings to save energy.

Heat pump is the modern expression for the refrigeration system in which heat discharged at the condenser is of prime importance. Heat pump is a device which collects heat from one source and delivers it to another source using refrigeration cycle. The medium being cooled serves as heat source. Heat is picked up by the refrigerant, which is pumped to the higher level by the compressor and given to the medium cooling the condenser, so that it can be used practically.

The heat pump required the availability of a dependable heat source in sufficient quantity that can supply heat to evaporator (or can be cooled by it). The basic heat sources that normally used are air, water and earth. When heat pumps are installed, frequently provision is made for both, heating and cooling services to be supplied simultaneously to the separate zones of the building.

Precautions:

- **Make proper earthing for the unit.**
- Make sure that the storage tank carries sufficient quantity of water.
- **Do not start the equipment if**
 - 1) Pressures on H.P. & L.P. sides not equalized.
 - 2) **Condenser and evaporator flow rates are not maintained.**
- The charging valve provided should not be opened unless required for charging.
- **Do not increase the water flow rates beyond limit.**
- For restarting the plant wait for some time.
- **Drain the water from tank when not in use.**

Procedure:

- 1. Switch ON the main switch and then start the pump.**
2. Start the water supply to both, condenser and evaporator and adjust the flowrate to predetermined value.
- 3. Now, start the compressor within a short period, clear liquid refrigerant flow will be seen in the rotameter.**
4. After some time, the pressure of refrigeration system will become stable. Allow the plant to run for at least half an hour. During testing, see that water flow rates are constant and not varying.
- 5. Allow the plant to attain steady state. Check for steady state by taking the readings periodically.**
6. Take all readings as mentioned in the observation table, completing one set of observations.
- 7. By varying the water flow rate of condenser, effect of sub-cooling can be studied. Similarly, by varying water flow rate of evaporator, load on the plant can be varied.**

The Apparatus:

Mechanical heat pump is a table mounted unit which uses water as a heat source and sink for both cooling and heating purposes, i.e. it is a water to water heat pump. The apparatus consists of the compressor is mounted centrally and both evaporator and condenser are mounted on either sides of compressor. All the components are mounted on the main unit and separate control panel is provided in which measurement of temperature and compressor power can be done. A separate storage tank is provided with a self-priming fractional horse power monoblock pump with flow control arrangement for constant velocity flow through the circuit. To expand the range of experimentation, control valves are provided in the water circuit so that water flow rates can be changed and different experiments are possible over a wide range of conditions.

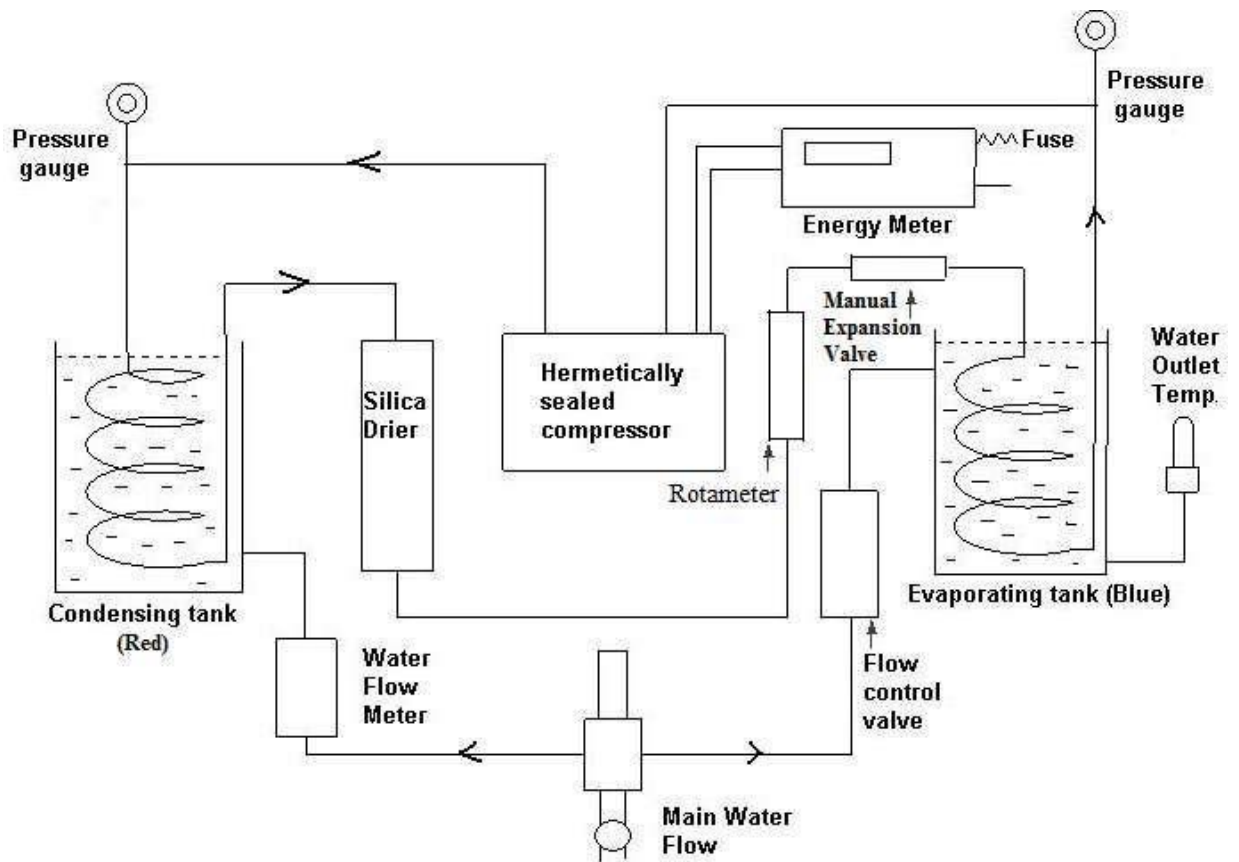


Fig. Mechanical Heat Pump

**Observation Table:
Refrigeration cycle**

Sr.No	Description	Symbol	Readings
1	Condensing Pressure	Pc	
2	Evaporator Pressure	Pe	
3	Flow rate of refrigerant in LPH	Mr	
4	Condensing inlet Temp	T1	
5	Condensing outlet Temp	T2	
6	Evaporator inlet Temp	T3	
7	Evaporator Outlet Temp	T4	
8	Compressor energy - Timefor 10 Flashes	Sec.	

Condenser Side

Sr.No	Description	Symbol	Readings
1	Water flow rate in LPH	Mc	
2	Water temp inlet	T6	
3	Water temp Outlet	T5	

Evaporator Side

Sr.No	Description	Symbol	Readings
1	Water flow rate in LPH	Me	
2	Water temp inlet	T6	
3	Water temp Outlet	T7	

Calculations:

A) Plant operating as Refrigeration cycle:

1) Theoretical COP = $\frac{H_{eo} - H_{ei}}{H_{ci} - H_{eo}}$

2) Actual COP = $\frac{\text{Heat absorbed in evaporator from water}}{\text{compressor work}}$

Heat absorbed in evaporator from water = $M_e \times C_p \times \Delta T_e$

kj/

hr Where

M_e = mass flow rate of water in Evaporator Kg/hr C_p =

Specific heat of water = 4.2 KJ/kg⁰c

ΔT_e = Temp. Diff. of Water in

Evaporator Compressor

Work = $\frac{10 \times 3600}{t_c \times EMC}$

*tc * EMC*

Where

T_c = Time for 10 flashes of energy meter in

sec EMC = Energy meter constant = 3200

Flashes/Kwhr

3) Condenser Heat output = $M_c \times C_p \times \Delta T_c$ kj/hr

M_c = mass flow rate of water in Condenser

Kg/hr C_p = Specific heat of water = 4.2 KJ/kg⁰c

ΔT_c = Temp. Diff. of Water in Condenser

4) Cooling capacity of

$\frac{\text{plant}}{\text{hr}} = \frac{\text{Heat absorbed in evaporator in kj}}{12600}$ Tons of Refrigeration

B) Cycle operating as Heat Pump

1) Theoretical COP = $\frac{H_{ci} - H_{co}}{H_{ci} - H_{eo}}$

$$2) \text{ Actual COP} = \frac{\text{Heat given in conenser to water}}{\text{compressor work}}$$

Conclusion: With the help of above data we can determine the COP of mechanical

HeatPumpActual COP=

Theoretical COP=