INTERNAL COMBUSTION ENGINES

LABORATORY MANUAL

UET

DEPARTMENT OF MECHANICAL ENGINEERING (KSK CAMPUS)

UNIVERSITY OF ENGINEERING & SCIENCE TECHNOLOGY

LAHORE

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Preface

In most of the engineering institutions, the laboratory course forms an integral form of the basic course in Internal Combustion Engines at undergraduate level. The experiments to be performed in a laboratory are ideally designed in such a way as to reinforce the understanding of the basic principles as well as help the students to visualize the various phenomenon encountered in different applications.

The objective of this manual is to familiarize the students with practical skills, measurement techniques and interpretation of results. It is intended to make this manual self-contained in all respects, so that it can be used as a laboratory manual. In all the experiments, the relevant theory and general guidelines for the procedure to be followed have been given. Tabular sheets for entering the observations have also been provided in each experiment while graph sheets have been included wherever necessary.

It is suggested that the students should complete the computations, is the laboratory itself. However the students are advised to refer to the relevant text before interpreting the results and writing a permanent discussion. The questions provided at the end of each experiment will reinforce the students understanding of the subject and also help them to prepare for viva-voce exams.

General Instructions to Students

- The purpose of this laboratory is to reinforce and enhance your understanding of the fundamentals of Internal Combustion Engines. The experiments here are designed to demonstrate the applications of the basic Internal Combustion Engines principles and to provide a more intuitive and physical understanding of the theory. The main objective is to introduce a variety of classical experimental and diagnostic techniques, and the principles behind these techniques. This laboratory exercise also provides practice in making engineering judgments, estimates and assessing the reliability of your measurements, skills which are very important in all engineering disciplines.
- Read the lab manual and any background material needed before you come to the lab. You must be prepared for your experiments before coming to the lab.
- Actively participate in class and don't hesitate to ask questions. Utilize the teaching assistants. You should be well prepared before coming to the laboratory, unannounced questions may be asked at any time during the lab.
- Carelessness in personal conduct or in handling equipment may result in serious injury to the individual or the equipment. Do not run near moving machinery. Always be on the alert for strange sounds. Guard against entangling clothes in moving parts of machinery.
- Students must follow the proper dress code inside the laboratory. To protect clothing from dirt, wear a lab apron. Long hair should be tied back.
- Calculator, graph sheets and drawing accessories are mandatory.
- In performing the experiments, proceed carefully to minimize any water spills, especially on the electric circuits and wire.
- Make your workplace clean before leaving the laboratory. Maintain silence, order and discipline inside the lab.
- Cell phones are not allowed inside the laboratory.
- Any injury no matter how small must be reported to the instructor immediately.
- Wish you a nice experience in this lab

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List of Experiments

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Experiment No. 2	Identification and recognition of different parts EFi petrol engine.
Experiment No. 3	To investigate the function of glow plug on live diesel engine test bed.
Experiment No. 4	To investigate the cooling system of diesel engine.
Experiment No. 5	To investigate the lubrication system of diesel engine.
Experiment No. 6	To investigate the cooling system of petrol engine with dual fuel.
Experiment No. 7	To investigate the lubrication system of petrol engine with dual fuel.
Experiment No. 8	To investigate the cooling system of Efi petrol engine.
Experiment No. 9	To investigate the lubrication system of Efi petrol engine.

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INTRODUCTION

1 Internal Combustion Engine:

The internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine (ICE) the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy.

1.1 Classifications of Internal Combustion Engine:

Internal combustion engines can be classified in many ways on following basis:

1.1.1 Basic Design

According to the design, the internal combustion engines are of two types.

1.1.2 Reciprocating:

Engine has one or more cylinders in which pistons reciprocate back and forth. The combustion chamber is located in the closed end of each cylinder. Power is delivered to a rotating output crankshaft by mechanical linkage with the pistons.

1.1.3 Rotary:

Engine is made of a block (stator) built around a large non-concentric rotor and crankshaft. The combustion chambers are built into the non-rotating block. A number of experimental engines have been tested using this concept, but the only design that has ever become common in an automobile is the Wankel engine in several Mazda models. Mazda builds rotary automobile engines with one, two, and three rotors.

1.2 Types of ignition

According to type of ignition the internal combustion engines are of following types.

1.2.1 Spark Ignition (SI):

An SI engine starts the combustion process in each cycle by use of a spark plug. The spark plug gives a high voltage electrical discharge between two electrodes, which ignites the air

fuel mixture in the combustion chamber surrounding the plug. In early engine development, before the inventor of electric spark plug, many forms of torch holes were used to initiate combustion from an external flame.

1.2.2 Compression Ignition (CI):

The combustion process in a CI engine starts when the air-fuel mixture self-ignites due to high temperature in the combustion chamber caused by high compression.

1.3 Engine Working Cycle

There are basically two types of working cycles on which the internal combustion engines operates. These cycles are explained below.

1.3.1 Four-stroke cycle:

A four-stroke cycle has four piston movements over two engine revolutions for each cycle. The four strokes are Intake, compression, Expansion and Exhaust.

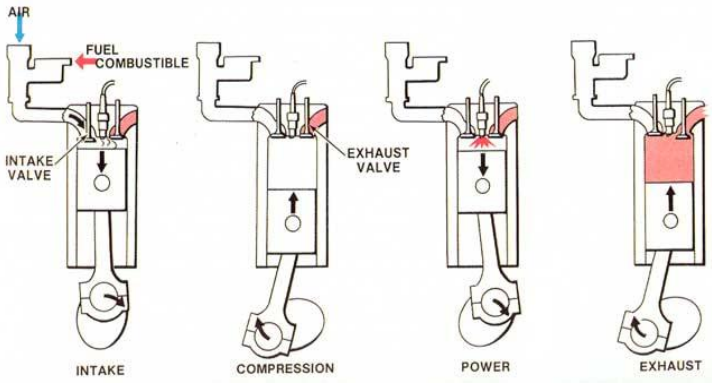

Figure 1.1: Four strokes of four stroke engine

1.3.2 Two-stroke cycle:

A two-stroke cycle has two piston movements over one revolution for each cycle. A two-stroke, two-cycle, or two-cycle engine is a type of internal combustion engine which completes a power cycle in only one crankshaft revolution and with two strokes, or up and down movements, of the piston in comparison to a "four-stroke engine", which uses four strokes to do so. This is accomplished by the end of the combustion stroke and the beginning of the compression stroke happening simultaneously and performing the intake and exhaust (or scavenging) functions at the same time.

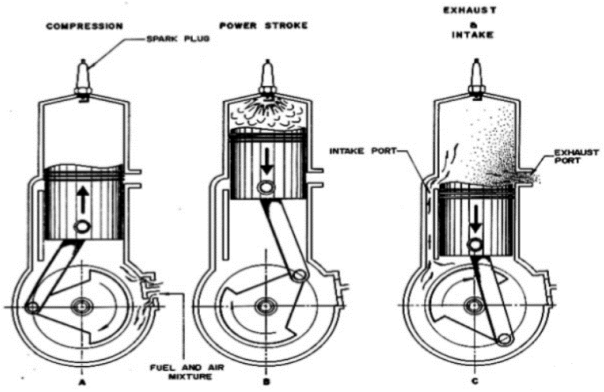

Figure 1.2.: Strokes of two strokes engine

1.4 Number of cylinders

The Internal combustion engines have different types according to the number of cylinders in the engine as explained bellow.

1.4.1 Single Cylinder:

Engine has one cylinder and piston connected to the crankshaft.

1.4.2 Multi-cylinder Engine:

Some Internal Combustion Engines contain more than one cylinder. These multi-cylinder engines have different types according to the arrangement of cylinders.

1.4.2.1 In-Line:

Cylinders are positioned in a straight line, one behind the other along the length of the crankshaft. They can consist of 2 to 11 cylinders or possibly more. In-line four-cylinder engines are very common for automobile and other applications. In-line six and eight cylinders are historically common automobile engines In-line engines are sometimes called Straight (e.g., straight six or straight eight).

1.4.2.2 V Engine:

V engines usually have even numbers of cylinders from 2 to 20 or more. V6s and V8s re common automobile engines, with V12s and V16s (historic) found in some luxury and high-performance vehicles. Large ship and stationery engines have anywhere from 8 to 20 cylinders.

1.4.2.3 Opposed Cylinder Engine:

Two banks of cylinders opposite to each other on a single crankshaft. These are common on small aircraft and some automobiles with an even number of cylinders from two to eight or more. These engines are often called flat engines (e.g., flat four).

1.4.2.4 W engine:

Engines of two different cylinder arrangements have been classified as W engines in the technical literature. One type is the same as a V engine except with three banks of cylinders on the same crankshaft. They are not common, but some race cars of 1930 s and some luxury cars of the 1990s had such engines either with 12 cylinders or 18 cylinders. Another type of W engine is the modern 16-cylinder engine made for the Bugatti automobile (W16). This engine is essentially two V8 engines connected together on a single crankshaft.

1.4.2.5 Opposed piston engine:

Two pistons in each cylinder with the combustion chamber in the centre between the pistons. A single combustion process causes two power strokes at the same time, with each piston being pushed away from the centre and delivering power to a separate crankshaft at each end of the cylinder. Engine output is either on two rotating crankshafts or on one crankshaft incorporating a complex mechanical linkage. These engines are generally of large displacement, used for power plants, ships, or submarines.

1.5 Governing cycles of SI and CI engines:

1.5.1 Otto Cycle:

An Otto cycle is an idealized thermodynamic cycle which describes the functioning of a typical spark ignition reciprocating piston engine, the thermodynamic cycle most commonly found in automobile engines.

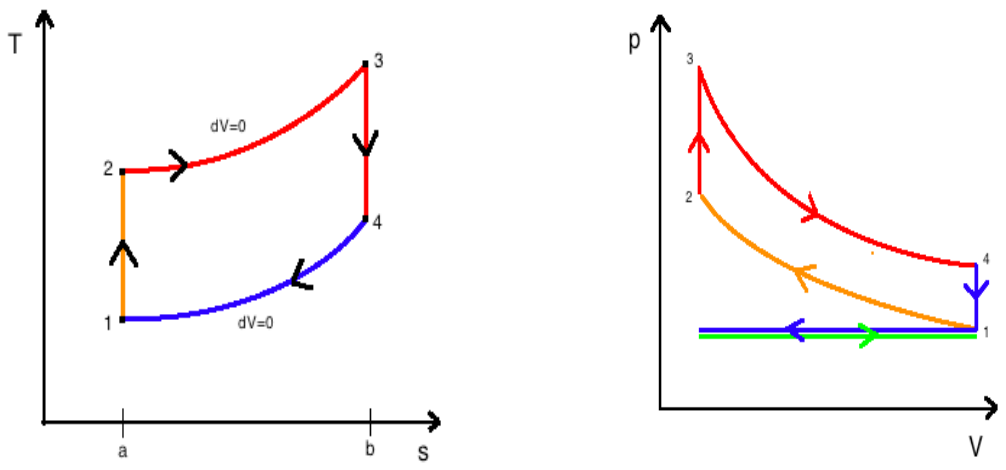

Figure 1.3: P-V and T-S diagram of Otto cycle

1.5.2 Diesel cycle:

The Diesel cycle is the thermodynamic cycle which approximates the pressure and volume of the combustion chamber of the Diesel engine, invented by Rudolph Diesel in 1897. It is assumed to have constant pressure during the first part of the "combustion" phase (V_2 to V_3 in the diagram, below). This is an idealized mathematical model: real physical Diesels do have an increase in pressure during this period, but it is less pronounced than in the Otto cycle.

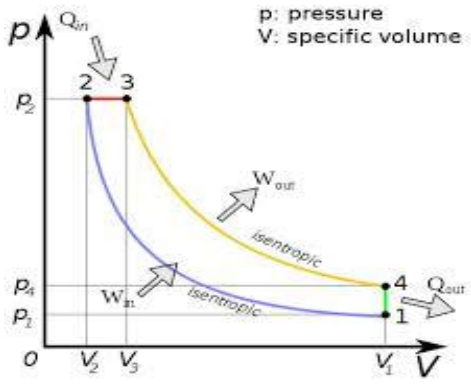

Figure 1.4: P-V diagram of Diesel cycle

2. LAB SESSION 1

Identification and recognition of different parts of four stroke diesel engine.

2.1 Learning Objectives

After this lab session students will be able:

1. To understand all the parts of diesel engine
2. To understand the working principle of diesel engine
3. To understand the operation of diesel engine

2.2 Apparatus

Cut out model of four stroke diesel engine

2.3 Main Parts

- Cylinder Block
- Piston
- Cylinder head
- Connecting rod
- Crankshaft
- Oil sump
- Camshaft
- Valves

2.4 Labelled diagram of Diesel Engine

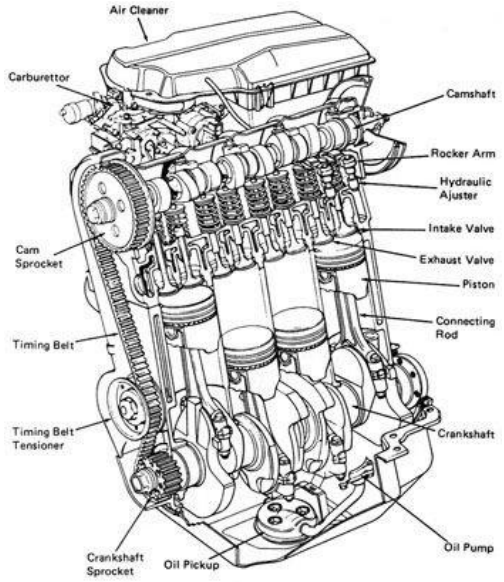

Figure 2.1 Labelled diagram of 4-stroke diesel engine

2.5 Description of main parts

2.5.1 Cylinder block

Cylinder block or Cylinder are main part of an engine. It is a part in which combustion of fuel takes place. All other parts like piston, connecting rod, crankshaft, water jacket etc. are bolted on it.

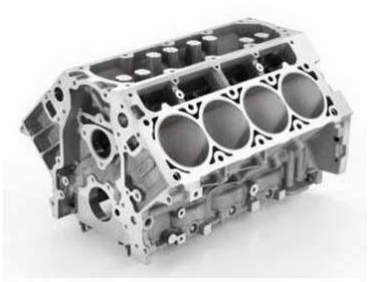

Figure 2.2 Cylinder Block

2.5.2 Piston

Piston is placed in the cylinder and transmits thrust to the connecting rod. It is free to move. It compresses the air fuel mixture and convert the fuel energy into mechanical energy. It transmits the power to the crankshaft.

Figure 2.3 Piston

2.5.3 Cylinder Head

Cylinder head is fitted on the top of cylinder block and the function of the cylinder head is to seal the working end of cylinder and not to permit entry and exit of gases on cover head valves of the engine. The valves, spark plug, camshaft etc are fitted on it.

Figure 2.1 Cylinder Head

2.5.4 Connecting Rod

It connects piston to the crank shaft and transmit the motion and thrust of piston to crankshaft. The lower end of connecting rod is connected to the piston and the bigger is connected to the crank shaft.

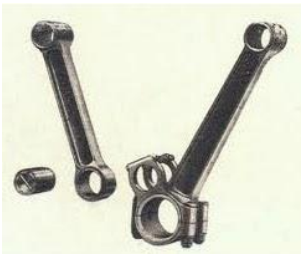

Figure.2.2 Connecting Rod

2.5.5 Crankshaft

It is located in the bottom end of cylinder block. It transmits the reciprocating motion of piston into rotary motion. This rotary motion used to rotate wheels of the vehicle.

Figure 2.3 Crankshaft

2.5.6 Oil Sump

It is bolted at the lower end of the cylinder block. All the oil for lubricating the movable parts is placed in it.

Figure .2.4 Oil Sump

2.5.7 Camshaft

It is fitted either in the cylinder head or at the bottom of the cylinder block. It is use to open or close valves at proper timing in multi-cylinder engine.

Figure.2.5 Camshaft

2.5.8 Valves

It is fitted on the cylinder head. It regulates the flow of air fuel mixture inside the cylinder and exhaust gas outside the cylinder block. When both inlet and exhaust valves are closed no pressure can go inside or outside of cylinder block.

Figure 2.6 Valves

2.5.9 Spark Plug

It is used in Petrol engine (Spark Ignition Engine). It is fitted on the cylinder head. It is used to ignite the air fuel mixture inside the cylinder at the end of each compression stroke.

Figure.2.7 Spark Plug

2.5.10 Injector

It is used in Diesel engine (Compression Ignition Engine). It is fitted on the cylinder head. It is used to inject fuel in spray form inside the cylinder at the end of compression stroke.

Figure 2.8 Injector

2.5.11 Push Rod

It is used when the camshaft is situated in the bottom of the cylinder head. It regulates the timing of valves open and close through rocker arm and camshaft.

Figure 2.9 Push Rods

2.5.12 Manifold

It is bolted on the cylinder head one each for intake and exhaust. Its function is to evenly distribute air-fuel mixture for intake & collects the exhaust gases from all cylinders.

Figure 2.10 Manifold

2.5.13 Piston Rings

It provides the good sealing fit and less friction resistance between piston and cylinder. It is split at one point so it can be easily installed into the grooves cut in the piston.

Figure 2.11 Piston Rings

2.5.14 Gaskets

It is used to seal the cylinder head and cylinder so no pressure is allowed to escape. It is placed between the cylinder block and cylinder head.

Figure 2.12 Gasket

2.5.15 Gudgeon Pin (Piston Pin)

It is the parallel spindles fitted through the piston boss and connecting rod small end. It connects the piston to the connecting rod.

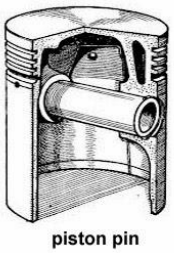

Figure 2.13 Gudgeon Pin

2.5.16 Engine Bearing

Bearings are used to support the moving parts. The purpose of bearings is to reduce friction. The crankshaft is supported by bearing. In engine two types of bearing are used sliding bearing and rolling bearing.

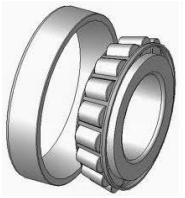

Figure 2.14 Bearings

2.6 Working Principle of Diesel Engine

The diesel engine differs from the gasoline powered Otto cycle by using highly compressed hot air to ignite the fuel rather than using a spark plug (compression ignition rather than spark ignition).

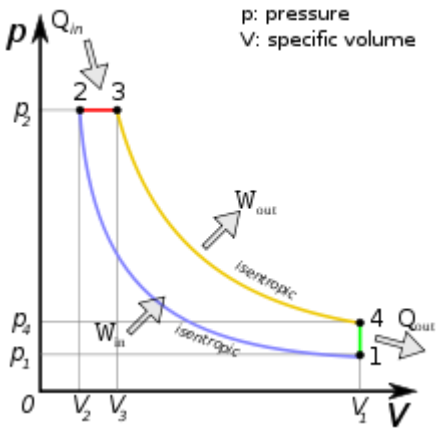

Figure 2.15 PV diagram for Diesel Engine

In diesel engine, only air is initially introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15:1 and 23:1. This high compression causes the temperature of the air to rise. At about the top of the compression stroke, fuel is injected directly into the compressed air in the combustion chamber. This may be into a void in the top of the piston or a pre-chamber depending upon the design of the engine. The fuel injector ensures that the fuel is broken down into small droplets, and that the fuel is distributed evenly. The heat of the compressed air vaporizes fuel from the surface of the droplets. The vapor is then ignited by the heat from the compressed air in the combustion chamber, the droplets continue to vaporize from their surfaces and burn, getting smaller, until all the fuel in the droplets has been burnt.

Combustion occurs at a substantially constant pressure during the initial part of the power stroke. The start of vaporization causes a delay before ignition and the characteristic diesel knocking sound as the vapor reaches ignition temperature and causes an abrupt increase in pressure above the piston.

When combustion is complete the combustion gases expand as the piston descends further; the high pressure in the cylinder drives the piston downward, supplying power to the crankshaft.

As well as the high level of compression allowing combustion to take place without a separate ignition system, a high compression ratio greatly increases the engine's efficiency. Increasing the compression ratio in a spark-ignition engine where fuel and air are mixed before entry to the cylinder is limited by the need to prevent damaging pre-ignition. Since only air is compressed in a diesel engine, and fuel is not introduced into the cylinder until shortly before top dead centre (TDC), premature detonation is not a problem and compression ratios are much higher.

2.6.1 PV Cycle:

The p–V diagram is a simplified and idealized representation of the events involved in a Diesel engine cycle, arranged to illustrate the similarity with a Carnot cycle.

Starting at 1, the piston is at bottom dead Centre and both valves are closed at the start of the compression stroke; the cylinder contains air at atmospheric pressure. Between 1 and 2 the air is compressed adiabatically—that is without heat transfer to or from the environment—by the rising piston. (This is only approximately true since there will be some heat exchange with the cylinder walls.) During this compression, the volume is reduced, the pressure and temperature both rise.

At or slightly before 2 (TDC) fuel is injected and burns in the compressed hot air. Chemical energy is released and this constitutes an injection of thermal energy (heat) into the compressed gas.

Combustion and heating occur between 2 and 3. In this interval the pressure remains constant since the piston descends, and the volume increases; the temperature rises as a consequence of the energy of combustion.

At 3 fuel injection and combustion are complete, and the cylinder contains gas at a higher temperature than at 2. Between 3 and 4 this hot gas expands, again approximately adiabatically. Work is done on the system to which the engine is connected. During this expansion phase the volume of the gas rises, and its temperature and pressure both fall.

At 4 the exhaust valve opens, and the pressure falls abruptly to atmospheric (approximately). This is unresisted expansion and no useful work is done by it. Ideally the adiabatic expansion should continue, extending the line 3–4 to the right until the pressure falls to that of the surrounding air, but the loss of efficiency caused by this unresisted expansion is justified by the practical difficulties involved in recovering it (the engine would have to be much larger).

After the opening of the exhaust valve, the exhaust stroke follows, but this (and the following induction stroke) are not shown on the diagram. If shown, they would be represented by a low-pressure loop at the bottom of the diagram.

At 1 it is assumed that the exhaust and induction strokes have been completed, and the cylinder is again filled with air. The piston-cylinder system absorbs energy between 1 and 2—this is the work needed to compress the air in the cylinder, and is provided by mechanical kinetic energy stored in the flywheel of the engine. Work output is done by the piston-cylinder combination between 2 and 4. The difference between these two increments of work is the indicated work output per cycle, and is represented by the area enclosed by the p–V loop. The adiabatic expansion is in a higher-pressure range than that of the compression because the gas in the cylinder is hotter during expansion than during compression. It is for this reason that the loop has a finite area, and the net output of work during a cycle is positive.

2.7 Advantages

- Diesel fuel has higher energy density
- A smaller volume of fuel is required to perform a specific amount of work.
- Heavier fuels like diesel fuel have higher cetane ratings and lower octane ratings, resulting in increased tendency to ignite spontaneously
- They have no high voltage electrical ignition system, resulting in high reliability and easy adaptation to damp environments

- For any given partial load, the fuel efficiency (mass burned per energy produced) of a diesel engine remains nearly constant, as opposed to petrol and turbine engines which use proportionally more fuel with partial power outputs
- The carbon monoxide content of the exhaust is minimal

3. LAB SESSION 2

Identification and recognition of different parts of EFi petrol engine.

3.1 Learning Objectives

After this lab session students will be able:

1. To understand all the parts of EFI Petrol engine.
2. To understand the working principle of EFI Petrol engine.
3. To understand the operation of EFI Petrol engine.

3.2 Apparatus

1. EFI petrol engine model

3.3 Theory:

3.3.1 S.I engine:

An SI engine starts the combustion process in each cycle by use of a spark plug. The spark plug gives a high voltage electrical discharge between two electrodes, which ignites the air fuel mixture in the combustion chamber surrounding the plug. In early engine development, before the inventor of electric spark plug, many forms of torch holes were used to initiate combustion from an external flame.

3.3.2 EFI Engine:

EFI stands for ELECTRONIC FUEL INJECTION. The Electronic Fuel Injection system fitted to most modern vehicles combines sophisticated computer controls with a high-pressure fuel delivery system to provide optimum power and fuel efficiency. The system is controlled by an electronic control unit (ECU).

3.3.3 Working Principal:

EFI is an indirect, pressurized injection system with injectors operated by a solenoid. In a multi-point injection system, each intake manifold has an injector. An electronic control unit helps to process the data from various sensors to optimize the fuel mixture. Fuel injection systems are comprised of a complex array of components that work together to supply fuel to the vehicle's engine. Electronic fuel injection system is controlled by an electronic control unit.

3.3.3.1 Working Cycle:

An Otto cycle is an idealized thermodynamic cycle which describes the functioning of a typical spark ignition reciprocating piston engine, the thermodynamic cycle most commonly found in automobile engines. It is shown below;

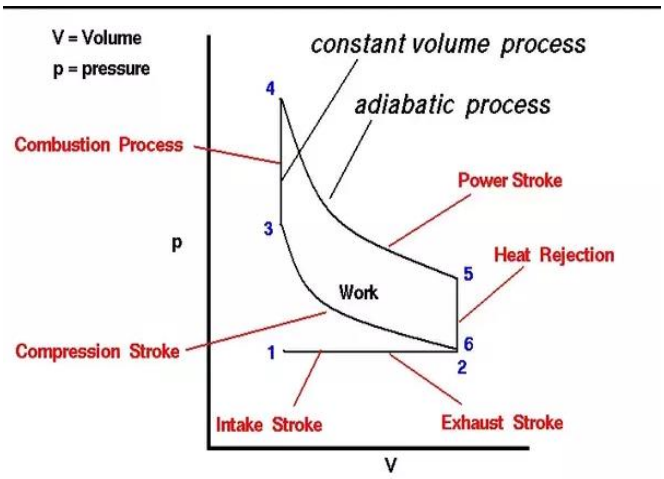

Figure 3.1: Otto cycle

3.3.4 Parts of Otto Engine:

1. Cylinder head
2. Piston
3. ECU
4. Cylinder
5. Connecting Rod
6. Gunging pin
7. Crank shaft
8. Rocker arm
9. Valves
10. Spark plug
11. Carburetor
12. Butterfly valve
13. Water Jacket:

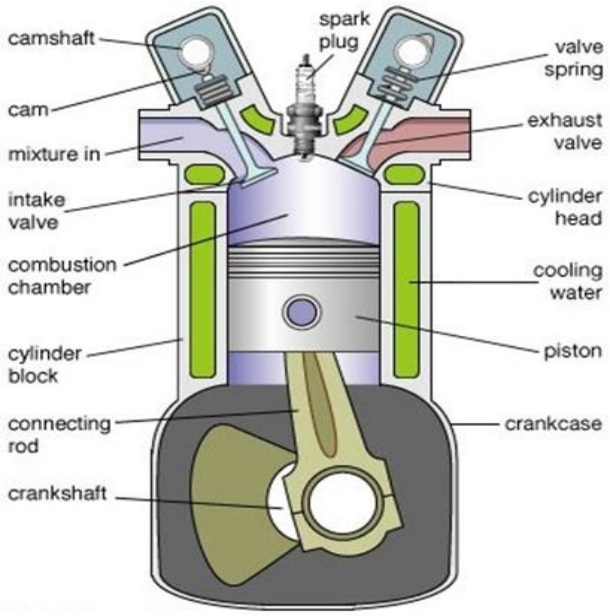

Figure 3.2: Parts of petrol engine

3.3.4.1 Cylinder head:

The head which consist of inlet and outlet valves, piston and cylinder.

3.3.4.2 Piston:

Piston is used to compress the fuel and to produce the power.

3.3.4.3 ECU:

Electronic control unit controls the amount of air and fuel required for power generation.

3.3.4.4 Cylinder:

The internal part of engine in which piston can slide up and down to produce the power required for the engine working.

3.3.4.5 Connecting Rod:

Connecting rod connects the piston with crank shaft. The basic purpose of connecting rod is to convert the rotatory motion of crank shaft in to translational motion of piston.

3.3.4.6 Gunging pin:

The pin which connects the piston and connecting rod.

3.3.4.7 Crank shaft:

The shaft which is connected with the piston and transfer the power from piston to flywheel.

3.3.4.8 Rocker arm:

Rocker arm is used to open and close the inlet and outlet valves by the crank rotation.

3.3.4.9 Valves:

There are two valves. The first valve is inlet valve, from which the fuel air mixture is enter. The second valve is outlet valve which is responsible for the removal of exhaust gasses from the piston which is produced after the end of combustion process.

3.3.4.10 Spark plug:

Spark plug is responsible for the burning of fuel. It produces a little spark which is enough to burn the fuel completely.

3.3.4.11 Carburetor:

It controls the Air Fuel ratio according to the load.

3.3.4.12 Butterfly valve:

The valve which controls the quantity of air required to complete burn the fuel according to the load variation.

3.3.4.13 Water Jacket:

System of liquid flow passages surrounding the cylinders, usually constructed as part of the engine block and head. Engine coolant flows through the water jacket and keeps the cylinder walls from overheating. The coolant is usually a water-ethylene glycol mixture. The water jacket is a casing containing water circulated by a pump used around a part to be cooled, especially in water-cooled internal-combustion engines.

3.3.5 Fuel injection system:

3.3.5.1 Electronic fuel injector (EFI):

The electric fuel pump usually comes in an in-tank module that consists of a pump, a filter, and a sending unit. The sending unit uses a voltage divider to tell your gas gauge how much fuel you have left in your tank. The pump sends the gasoline through a fuel filter, through hard fuel lines, and into a fuel rail. A vacuum-powered fuel pressure regulator at the end of the fuel rail ensures that the fuel pressure in the rail remains constant relative to the intake pressure. For a gasoline engine, fuel pressure is usually on the order of 35-50 psi. Fuel injectors connect to the rail, but their valves remain closed until the ECU decides to send fuel into the cylinders. When the plunger rises, it opens a valve and the injector sends fuel through the spray tip and into either the intake manifold, just upstream of the intake valve, or directly into the cylinder.

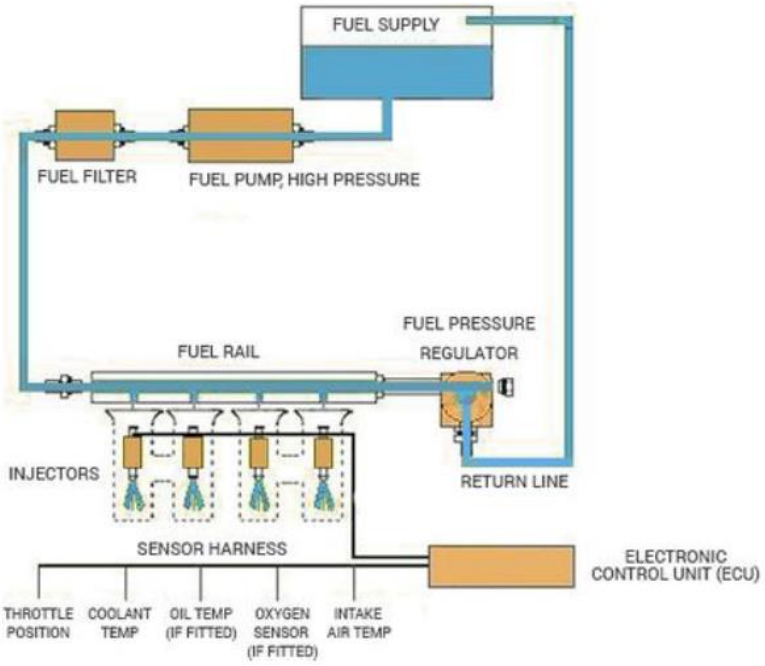

Figure 3.3: EFI System

4. Lab Session 3

4.1 Objective

To investigate the function of glow plug on live diesel engine test bed.

4.2 Labelled diagram of Glow Plug

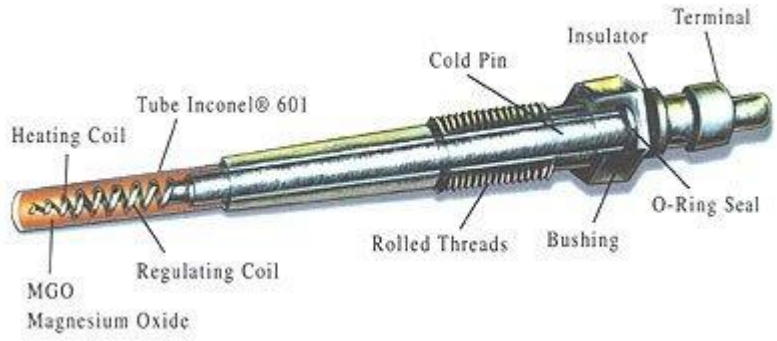

Figure 4.1 Labelled diagram of glow plug

4.3 Working of Glow Plug

Diesel engines are compression-ignition engines, which means the injected fuel ignites without the need for an ignition spark. The combustion cycle is triggered in three steps:

- First, clean air is taken in.
- 2. This air is compressed to 30–55 bar – during this process, it will heat up to 700–900 °C.
- 3. Diesel fuel is injected into the combustion chamber. The high temperature of the compressed air triggers auto-ignition, internal pressure strongly increases and the engine does its work.

Compared to spark-ignition engines, compression-ignition engines require complex injection systems and engine designs. The first diesel engines were not actually very convenient or smooth-running drive units. Due to the hard combustion process, they made a lot of noise when cold. Typical characteristics included a lower power-to-weight ratio, a low output per liter displacement as well as a lower acceleration performance. Through continuous development of the injection technology and the glow plugs, it was possible to eliminate all these disadvantages. Today, the diesel engine is considered an equivalent
or even better power source.

4.3.1 Cold Start

The term "cold start" describes all start processes occurring while the engine and the media involved have not reached operating temperature. The lower the temperature, the less favourable are the conditions for a quick ignition and complete, environmentally friendly combustion. Certain supporting measures are used to assist during the cold start and so that starting will not be unacceptably long or even impossible. These compensate for the poorer start conditions while initiating a well-timed and even ignition to ensure stable combustion.

The glow plug is one component that assists during cold start. It creates ideal ignition conditions for the injected fuel through electrically generated thermal energy that is brought into the combustion chamber. It is indispensable as cold start aid for engines with a divided combustion chamber, in order to ensure that these can start even in the frequently occurring temperature range of 10–30 °C. Since the start quality deteriorates considerably at below freezing point, the glow plug is also used as cold start aid for direct-injection diesel engines.

4.4 Requirements on a glow plug

4.4.1 Short heat-up time

Glow plugs must provide a high temperature within as short a time as possible to assist with ignition – and they must maintain this temperature regardless of the ambient conditions, or even adjust the temperature depending on them.

Small space requirement

Passenger car diesel engines with antechamber or turbulence chamber injection and direct Injection versions using 2-valve technology usually have enough space available for injection nozzles and glow plugs.

However, in modern diesel engines with common rail or pump-nozzle injection systems and 4-valve technology, the available space is very restricted. This means that the space required for the glow plug must be reduced to a minimum, resulting in a very thin and long shape. Today, BERU glow plugs with glow tube diameters reduced to <3 mm are already in operation.

4.4.2 Precise adaptation to the combustion chamber

Ideally, the glow rod should be situated precisely at the edge of the mixture vortex - however, it must still project sufficiently deep into the combustion chamber or the antechamber. Only then is it able to introduce the heat accurately. It may not protrude too far into the combustion chamber, as it would otherwise interfere with the preparation of the injected fuel and thus the

preparation of the mixture for an ignitable fuel-air mixture. This would result in increased exhaust gas emissions.

4.4.3 Sufficient glowing volume

Apart from the glow plug, the injection system is of particular significance in the engine cold start. Only a system that has been optimized in terms of its injection point, quantity and mixture composition in conjunction with the correct position and thermal rating of the glow plug will ensure good cold start performance. Even after the engine has been started, the glow plug may not be “blown cold” by the increased air movement in the combustion chamber. Very high air speeds are in particular present in antechamber or turbulence chamber engines at the glow plug tip. In this environment, the plug will only work if it has sufficient reserves; i.e. if sufficient glowing volume is available so that heat can immediately be brought on into the cold-blown zone.

The glow plugs developed by BERU fulfil all these requirements in an optimal manner. BERU engineers work closely with the automotive industry especially during the engine development stage. The result: an environmentally-sound diesel quick start in 2-5 seconds (in conjunction with the Instant Start System ISS a maximum of 2 seconds), a reliable start up to –30 °C, a steady engine start-up that is gentle on the engine, with up to 40 % less carbon-particulate emissions in the warm-up phase for post-heating glow plugs.

5. LAB SESSION 4

To study the parts and working of the cooling system for Diesel Engines.

5.1 Learning Objectives:

After completing this experiment, students will be able to

- Recognize the corresponding components of cooling system.
- Understand the working principles of cooling system.
- Understand the function of radiator.

5.2 Apparatus

Diesel Engine Test Bed

5.3 Theory:

Combustion of the air fuel mixture in the cylinders generates heat which produces high pressure, to force the piston down in the power stroke. Not all of this heat can be converted into useful work on the piston, and it must be removed to prevent seizure of moving parts. This is the role of the cooling system. Most engines are liquid cooled.

A liquid-cooled system uses water coolant. Basically, coolant flows through passages in the engine and through a radiator. The radiator accepts hot coolant from the engine,and lowers its temperature. Air flowing around, and through the radiator takes heat from the coolant.

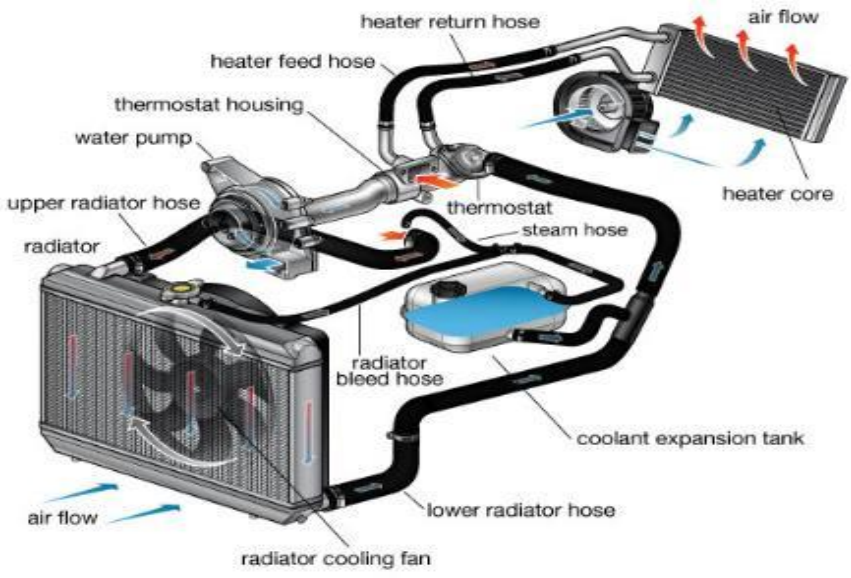

Figure 5.1: Cooling system and its parts

5.3.1 COMPONENTS OF A COOLING SYSTEM:

- The Radiator
- Radiator Cooling Fans
- Pressure Cap & Reserve Tank
- Water Pump
- Thermostat
- Bypass System
- Freeze Plugs
- Head Gaskets & Intake Manifold Gaskets

5.3.1.1 4.3.1 Radiator:

The radiator core is usually made of flattened aluminum tubes with aluminum strips that zigzag between the tubes. These fins transfer the heat in the tubes into the air stream to be carried away from the vehicle. On each end of the radiator core is a tank, usually made of plastic that covers the ends of the radiator.

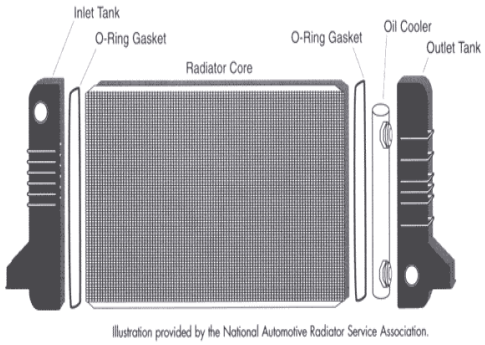

Figure 5.2: Radiator and its parts

5.3.1.2 Radiator Fan:

Mounted on the back of the radiator on the side closest to the engine is one or two electric fans inside a housing that is designed to protect fingers and to direct the air flow. These fans are there to keep the air flow going through the radiator while the vehicle is going slow or is stopped with the engine running. If these fans stopped working, every time you came to a stop, the engine temperature would begin rising.

Figure 5.3: Radiator fan

5.3.1.3 Pressure cap and reserve tank

As coolant gets hot, it expands. Since the cooling system is sealed, this expansion causes an increase in pressure in the cooling system, which is normal and part of the design. When coolant is under pressure, the temperature where the liquid begins to boil is considerably higher. This pressure, coupled with the higher boiling point of ethylene glycol, allows the coolant to safely reach temperatures in excess of 250 degrees.

Figure 5.4: Radiator pressure cap

The radiator pressure cap is a simple device that will maintain pressure in the cooling system up to a certain point. If the pressure builds up higher than the set pressure point, there is a spring loaded valve, calibrated to the correct Pounds per Square Inch (psi), to release the pressure.

5.3.1.4 Water Pump:

A water pump is a simple device that will keep the coolant moving as long as the engine is running. It is usually mounted on the front of the engine and turns whenever the engine is running. The water pump is made up of a housing, usually made of cast iron or cast aluminum and an impeller mounted on a spinning shaft with a pulley attached to the shaft on the outside of the pump body. A seal keeps fluid from leaking out of the pump housing past the spinning shaft. The impeller uses centrifugal force to draw the coolant in from the lower radiator hose and send it under pressure into the engine block. There is a gasket to seal the water pump to the engine block and prevent the flowing coolant from leaking out where the pump is attached to the block.

5.3.1.5 Thermostat:

The thermostat is simply a valve that measures the temperature of the coolant and, if it is hot enough, opens to allow the coolant to flow through the radiator. If the coolant is not hot enough, the flow to the radiator is blocked and fluid is directed to a bypass system that allows the coolant to return directly back to the engine. The bypass system allows the coolant to keep moving through the engine to balance the temperature and avoid hot spots. Because flow to the radiator is blocked, the engine will reach operating temperature sooner and on a cold day, will allow the heater to begin supplying hot air to the interior more quickly.

5.3.1.6 Bypass System:

This is a passage that allows the coolant to bypass the radiator and return directly back to the engine. Some engines use a rubber hose, or a fixed steel tube. In other engines, there is a cast in passage built into the water pump or front housing. In any case, when the thermostat is closed, coolant is directed to this bypass and channeled back to the water pump, which sends the coolant back into the engine without being cooled by the radiator.

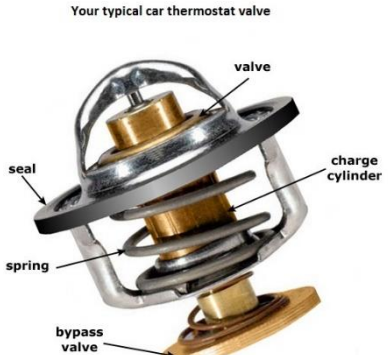

Figure 5.5: Thermostat valve in cars

5.3.1.7 Head Gaskets and Intake Manifold Gaskets:

All internal combustion engines have an engine block and one or two cylinder heads. The mating surfaces where the block and head meet are machined flat for a close, precision fit, but no amount of careful machining will allow them to be completely water tight or be able to hold back combustion gases from escaping past the mating surfaces.

In order to seal the block to the heads, we use a head gasket. The head gasket has several things it needs to seal against. The main thing is the combustion pressure on each cylinder. Oil and coolant must easily flow between block and head and it is the job of the head gasket to keep these fluids from leaking out or into the combustion chamber, or each other for that matter.

5.4 PROCEDURE:

- The water level in the engine is checked prior to starting the experiment and necessary deterrents are taken.
- After the water inspection the engine is started, if the engine does not start then preheating using glow plug may be required which is done by turning the key counter clockwise and holding for a few seconds.
- Now that the engine has started, we set a base engine speed (say 800 rpm), and proceed with our experiment.
- We note the corresponding values of inlet and outlet water temperature, given to us by sensors and dial connected to the engine apparatus, for given value of engine speed.
- Increase the engine speed with suitable increments and note corresponding values of inlet and outlet water temperature.

5.5 OBSERVATIONS AND CALCULATIONS:

TABLE 1:

No. of Observations	Engine Speed (rpm)	Time (min)	Water Temperature Gauge	Engine Water Inlet Temperature T3 (ºC)	Engine Water Outlet Temperature T4(ºC)	Ambient Temperature T6 (ºC)
1						
2						
3						

GRAPH:

5.6 COMMENTS:

6. LAB SESSION 5

To study the parts and working principle of the diesel engine lubrication system.

6.1 Learning Objectives:

- Inspect Engine Oil Level and condition.
- Ensure that the lubrication system is working properly
- Relationship between engine speed, oil temperature and oil pressure.

6.2 Apparatus

Diesel Engine Test Bed

6.3 THEORY:

An internal combustion engine would not run for even a few minutes if the moving parts were allowed to make metal-to-metal contact. The heat generated due to the tremendous amounts of friction would melt the metals, leading to the destruction of the engine. To prevent this, all moving parts ride on a thin film of oil that is pumped between all the moving parts of the engine. Once between the moving parts, the oil serves two purposes.

One purpose is to lubricate the bearing surfaces. The other purpose is to cool the bearings by absorbing the friction generated heat. The flow of oil to the moving parts is accomplished by the engine's internal lubricating system.

Oil is accumulated and stored in the engine's oil pan where one or more oil pumps take suction and pump the oil through one or more oil filters as shown in Figure 1. The filters clean the oil and remove any metal that the oil has picked up due to wear. The cleaned oil then flows up into the engine's oil galleries. A pressure relief valve(s) maintains oil pressure in the galleries and returns oil to the oil pan upon high pressure. The oil galleries distribute the oil to all the bearing surfaces in the engine.

Once the oil has cooled and lubricated the bearing surfaces, it flows out of the bearing and gravity-flows back into the oil pan. In medium to large diesel engines, the oil is also cooled before being distributed into the block. This is accomplished by either an internal or external oil cooler. The lubrication system also supplies oil to the engine's governor.

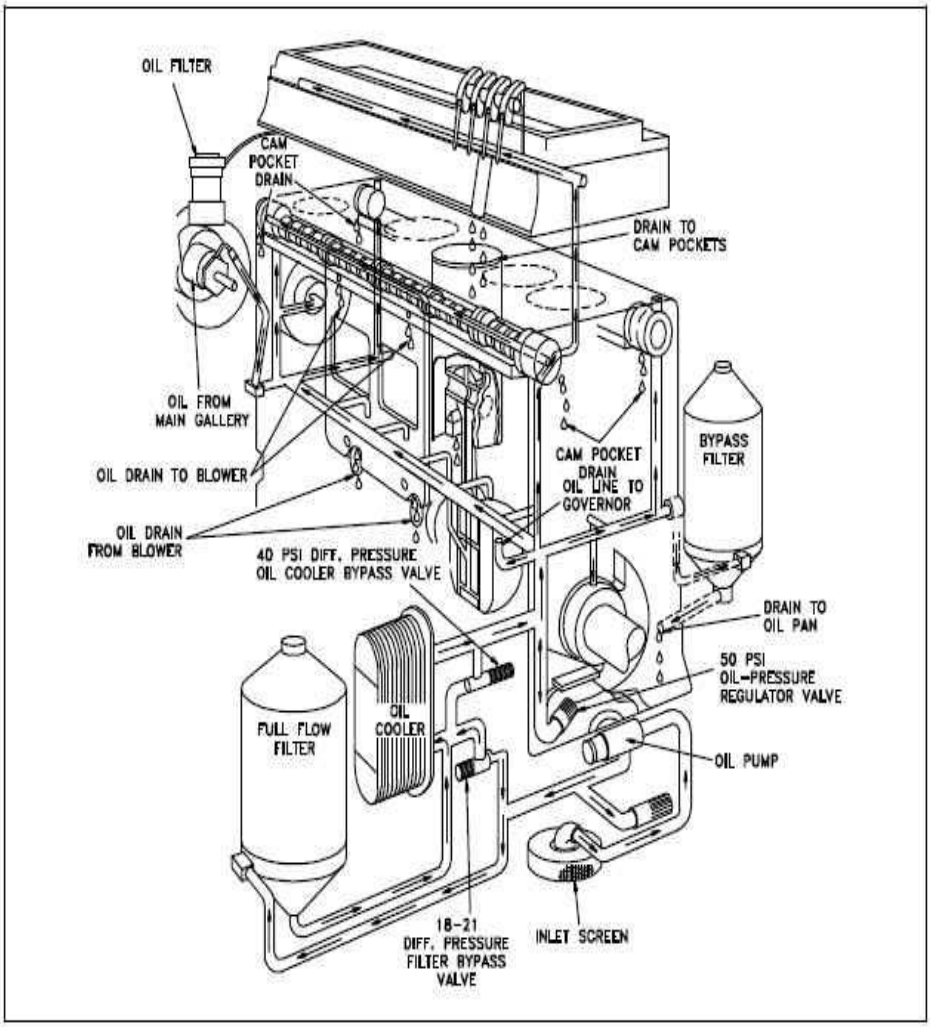

Figure 12 Diesel Engine Internal Lubrication System

Figure 6.1: Lubrication System

6.3.1 PARTS OF A DIESEL ENGINE LUBRICATING SYSTEM:

The main parts of the lube oil system are listed below:

- Oil Pumps
- Oil Filters
- Oil Cooler
- Oil manifold
- Oil Sump

6.3.1.1 Oil pumps:

The engine driven oil pump: usually positive displacement gear-driven pump. It pulls oil from the lube oil pan (sump) and supplies it to the engine when the engine is running. Pre-lube oil pump: In the larger engines the pre-lube pump is generally a close coupled, self-priming, positive displacement pump of the rotary lobe or gear type.

6.3.1.2 Oil filters:

The function of the filters is to clean the oil and remove any metal that the oil has picked up due to wear, and depending on its temperature it may pass through the oil coolers or not before it goes to the engine bearing inside the engine through the oil main gallery inside the cylinder block.

6.3.1.3 Oil cooler:

The lube oil cooler assembly generally uses shell and tube heat exchanger. Depending on the lube oil flow rate, a single heat exchanger may be used or two or more units may be used.

6.3.1.4 Oil manifold:

The oil galleries distribute the oil to all the bearings surfaces in the engine.

6.3.1.5 Oil sump:

The oil sump is where the oil is accumulated and stored in the engine.

6.4 PROCEDURE:

- The oil level in the engine is checked prior to starting the experiment and necessary precautions are taken.
- After the oil inspection the engine is started, if the engine does not start then preheating using glow plug may be required which is done by turning the key counter clockwise and holding for a few seconds.
- Now that the engine has started, we set a base engine speed (say 800 rpm), and proceed with our experiment.
- We note the corresponding values of oil pressure and oil temperature, given to us by sensors and dial connected to the engine apparatus, for given value of engine speed.
- Increase the engine speed with suitable increments and note corresponding values of oil temperature and pressure.

6.5 OBSERVATIONS AND CALCULATIONS:

TABLE 2:

No of observations	Engine speed (rpm)	Time (min)	Oil Pressure (Psi)	Oil Temperature (^oC)
1				
2				
3				

GRAPHS:

6.6 COMMENTS:

- Increasing the engine rpm's will increase the oil pressure and temperature.
- Engine lubrication system should have filter in order to remove dust particles from the lubrication oil.
- Before performing the session, we should have to apply pressure on priming pump so that the oil will somehow rises from the oil sump.

7. LAB SESSION 6

To study the parts and working principle of cooling system in EFI Engine.

7.1 OBJECTIVES:

- Study main parts of cooling system.
- Learn the working principle of cooling system.

7.2 THEORY:

7.2.1 Introduction:

EFI stands for Electronic Fuel Injection. The EFI system is fitted to most modern vehicles combines sophisticated computer controls with a high pressure fuel delivery system to provide optimum power and fuel efficiency. The system is controlled by ECU (Electronic Control Unit).

These systems often have anything in excess of thirty different engines and emission sensors all sending information continuously to the ECU. The ECU then monitors that information from the sensors and ensures the correct amount of fuel and air is used to provide optimum fuel efficiency and performance and also minimize exhaust emissions.

7.2.2 Common problems:

EFI problems can be caused by dirty fuel or a blocked injector. Sometimes, the fault has to be found somewhere within the EFI system using advanced diagnostic testers. Common symptoms include; poor fuel economy, backfiring, running on when the car is turned off and rough idling.

7.2.3 Cooling System and its development:

By changing how the cooling system operates, auto manufacturers are able to continue to increase fuel economy and power output. The technical changes have developed very gradually. In the beginning, a few turn-of-the-century auto manufacturers relied on a thermal-expansion cooling system that was based upon the tendency of hot water to rise out of the engine cylinder head into the top of a vertical-core radiator, where it would condense and re-enter the bottom of the engine block.

Although thermal expansion systems worked well on low-output engines, they couldn’t cool the high-speed engines introduced in the 1920s. These made engine-driven water pumps come into common usage early in the century. Thermostats operated by wax pellets or thermostatic springs also came into common usage during the 1920s to warm the engine faster and maintain even operating temperatures. Further refinements included a cooling system bypass system designed to circulate coolant throughout the engine while it’s warming up. Some engines also use double-seat thermostats to close the bypass when the thermostat opens, and pressurized cooling systems were introduced to prevent coolant boil-over on hot days.

The first cooling fans were conveniently mounted on the engine-driven water pumps and still are today. During the 1960s, cooling fans were mounted on temperature-sensitive fan

clutch devices to reduce power loss at the engine crankshaft. The 1960s and ’70s also saw horizontal-core radiators being introduced to accommodate reduced body height and increased cooling system demand. Many horizontal-core radiators also require remote coolant reservoirs to help evacuate air from the cooling system. Electric cooling fans began to appear on many imports because they could be activated only when engine temperatures reached a critical point. This eliminated the power loss associated with mechanical fans, and also increased fuel economy and reduced cold-engine exhaust emissions by reducing engine warm-up time. To further reduce emissions, thermostat opening temperatures were increased to about 195° F.

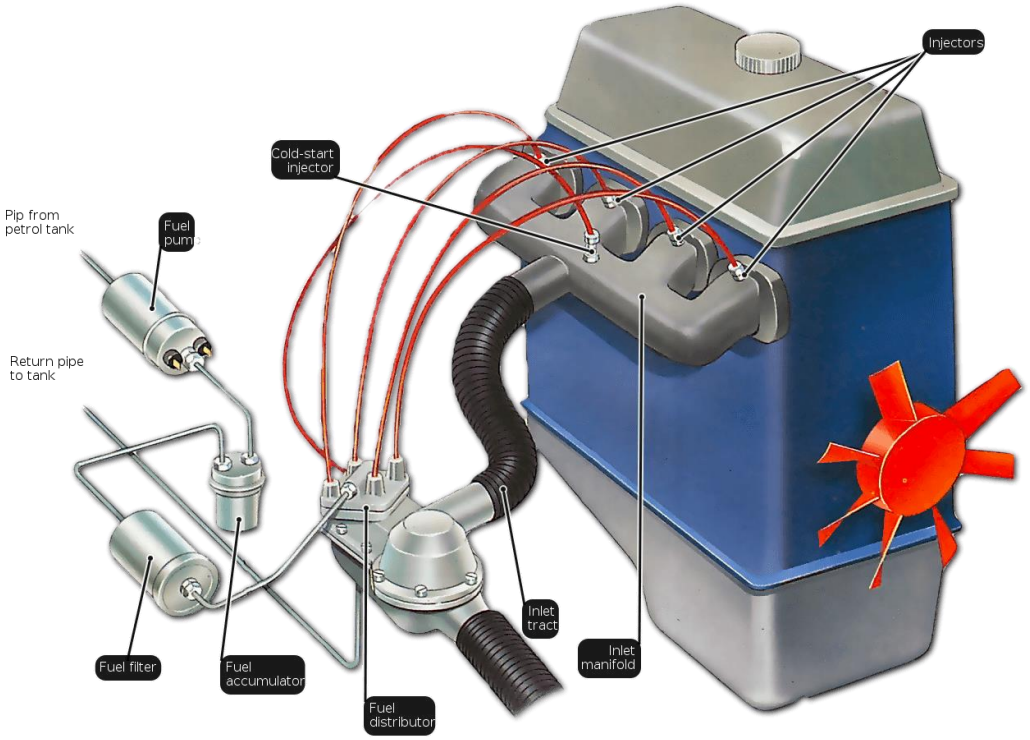

Figure 7.1: EFI Cooling system

7.2.4 Cooling system Components:

7.2.4.1 Water Pump:

The basic belt-driven water pump design in most applications hasn’t changed for many years. Most water pumps are centrifugal designs with cast or stamped metal impellors. But, some designs use molded plastic impellors. The water pump must produce enough volume to cool the engine at idle and also at full speed and power output.

In concert with water pump design, thermostats are designed to slightly restrict coolant flow from the engine. This restriction allows the water pump to build additional pressure in the engine water jackets to further reduce surface boiling on the cylinder heads and to reduce pressure on the radiator header tank at high engine speeds.

At higher engine speeds, the water pump begins to “cavitate,” which means that the water pump speed has reached the point at which most of the coolant is no longer contacting

the water pump impellor. At this point, a negative pressure develops along the surfaces of the water pump impellor that increases the tendency of the coolant to boil and the engine to overheat. In extreme cases, cavitation can erode water pump impellors and housings.

Many performance engine builders address this problem by installing special pulleys to reduce water pump speed. Modern auto manufacturers are similarly addressing the cavitation problem with electric water pumps.

In contrast to a belt-driven pump, the electric water pump avoids cavitation by running at a constant or at a selected, pre-programmed speed. It also increase the engine's power and fuel economy by eliminating another belt-driven accessory to reduce rotating friction.

7.2.4.2 Cylinder head temperatures:

Conventional thermostats like this badly corroded example might become a thing of the past. Increasing the engine's compression ratio can increase power and fuel economy, but detonation, which is the sudden and spontaneous combustion of fuel contained inside the combustion chamber, is the downside of increasing compression ratio.

The force of detonating fuel is such that it breaks spark plug insulators, piston rings and pistons. Since the early 1970s, the elimination of ethyl lead has basically limited compression ratios to about 9:1 at sea level conditions to eliminate detonation.

Since an aluminum cylinder head reduces combustion chamber surface temperatures, compression ratios can be slightly increased without introducing detonation. Electronic engine controls further reduce detonation by adjusting spark timing and exhaust gas recirculation rates. Knock sensors built into most engine management systems are designed to reduce spark advance if detonation is detected.

In contrast, the recent popular introduction of direct fuel injection systems, in which fuel is injected directly into the combustion chamber, also allows compression ratio increases ranging up to 13:1 on some applications. This increase is possible because the combustion process is precisely controlled and the fuel is injected into the cylinders in a manner that helps reduce combustion chamber temperatures.

Reducing cylinder head temperatures reduces the tendency of an engine to detonate. Some high-end manufacturers have introduced reverse-flow cooling systems in which the return coolant from the radiator flows into the cylinder heads rather than the water pump.

Reducing cylinder head temperatures also reduces fuel economy and increases the tendency of an engine to develop crankcase sludge. At the other temperature extreme, fuel atomizes better when it's exposed to higher coolant temperatures. So it's obvious that having full control of the engine coolant temperature can increase performance and fuel economy.

7.2.4.3 Electronic Therm**ostats:**

While originally introduced on high-end imports, one of two types of electronic thermostats will undoubtedly be found on our future commuter vehicles. The first type is basically a conventional thermostat that is opened by electrically heating the surrounding coolant. The second type is a new design in which the thermostat opening is directly

electronically controlled. In either case, the powertrain control module (PCM) will use these types of thermostats to regulate engine temperature to match the demands of part-throttle and wide-open throttle operation.

Figure 7.2: Thermostat

7.2.4.4 Cooling system issues:

Automotive engineers are currently faced with increasing the efficiency of the cooling system while reducing cooling system weight. Because many original equipment radiators have marginal cooling capacity, internally or externally clogged radiator core tubes will reduce cooling system performance to the point of overheating.

Electrolysis is, perhaps, the worst problem associated with modern bi-metal engines using aluminum radiators, whereas internal rust corrosion is the worst problem on the older cast-iron engines equipped with brass radiators. So, the additive packages in most coolants contain inhibitors that reduce corrosion caused by rust and electrolysis.

When the coolant's additive package wears out, rust flakes from the engine's cast-iron water jackets begin to clog the radiator core tubes. In some rare cases, the water pump impellor and other sheet-steel cooling system components like core plugs will also corrode due to poor metallurgy. In any case, rusty coolant indicates that the cooling system is headed for trouble.

Electrolysis occurs because a very mild electrical current develops between two dissimilar metals exposed to water-based solutions. Unfortunately, electrolysis tends to transfer from one metal to another. This results in the "solder bloom" found on the cores of the old soldered brass radiators. In more modern engines, electrolysis can cause cylinder head gasket failure by severely pitting cylinder head gasket surfaces and eroding the metallic portions of the gaskets themselves.

In the current market, most auto manufacturers supply long-life coolants designed to function with the specific metallurgy and designs of their cooling systems. Most manufacturers address deterioration in their additive packages by recommending scheduled coolant changes.

7.2.5 Cooling system service tips:

The contamination on the flat side of this timing belt came from a leaking water pump. Since a vehicle's temperature gauge indicates only that the vehicle operating temperature is generally within normal ranges, scan tools are essential for diagnosing late-model cooling systems. Normal ranges include thermostat opening temperatures now exceeding 200° F and cooling fans that might not activate until operating temperatures exceed 230° F. At the very least, the coolant and intake air temperatures displayed on the data stream should closely match those taken with a non-contact pyrometer.

Also check for DTCs indicating a pending or history code problem with thermostatic temperature control or coolant levels. Check cooling fan operation by turning on the air conditioner with the engine running. If your scan tool has bi-directional capability, cycle the cooling fans through their various speed ranges. Always check high-speed fan operation to ensure that the engine will cool in high-demand situations.

Visually check for debris accumulating between the air conditioner condenser and radiator. Also check for external leaks, drive belt condition, and cracked or hardened coolant hoses. Visually inspect the coolant level and color. Rusty or off-colored coolants might indicate that the coolant needs to be flushed. Low coolant levels indicate internal or external leakage.

Always replace suspect coolant with original equipment or manufacturer-approved coolants. Because mixing various types of coolants will reduce their freezing and boiling points.

7.3 PROCEDURE:

- The water level in the engine is checked prior to starting the experiment and necessary deterrents are taken.
- After the water inspection the engine is started, if the engine does not start then preheating using glow plug may be required which is done by turning the key counter clockwise and holding for a few seconds.
- Now that the engine has started, we set a base engine speed (say 800 rpm), and proceed with our experiment.
- We note the corresponding values of inlet and outlet water temperature, given to us by sensors and dial connected to the engine apparatus, for given value of engine speed.
- Increase the engine speed with suitable increments and note corresponding values of inlet and outlet water temperature.

7.4 OBSERAVTIONS & CALCULATIONS:

Table 3:

No. of Observations	Engine Speed (rpm)	Time (min)	Water Temperature Gauge	Engine Water Inlet Temperature T3 (^oC)	Engine Water Outlet Temperature T4(^oC)	Ambient Temperature T6 (^oC)
1.						
2.						
3.						

GRAPH:

7.5 COMMENTS:

8. LAB SESSION 7

To study the parts and working principle of Lubricating System EFI Engine**.**

8.1 OBJECTIVES:

- Study the parts of Lubricating system of EFI Engine.
- Working Principle of EFI lubricating system.

8.2 THEORY:

8.2.1 Introduction:

If the heart of a car is its engine, then its brain must be the Engine Control Unit (ECU). Also known as a Powertrain Control Module (PCM), the ECU optimizes engine performance by using sensors to decide how to control certain actuators in an engine. A car's ECU is primarily responsible for four tasks. Firstly, the ECU controls the fuel mixture. Secondly, the ECU controls idle speed. Thirdly, the ECU is responsible for ignition timing. Lastly, in some applications, the ECU controls valve timing.

Before we talk about how the ECU accomplishes its tasks, let's follow the path of a gasoline droplet that enters your gas tank. Times have changed since the *Down the Gasoline Trail* video, so it's time for an update. Initially, after a gas droplet enters your gas tank (which is now made of plastic), it gets sucked up by an electric fuel pump. The electric fuel pump usually comes in an in-tank module that consists of a pump, a filter, and a sending unit. The sending unit uses a voltage divider to tell your gas gauge how much fuel you have left in your tank. The pump sends the gasoline through a fuel filter, through hard fuel lines, and into a fuel rail.

A vacuum-powered fuel pressure regulator at the end of the fuel rail ensures that the fuel pressure in the rail remains constant relative to the intake pressure. For a gasoline engine, fuel pressure is usually on the order of 35-50 psi. Fuel injectors connect to the rail, but their valves remain closed until the ECU decides to send fuel into the cylinders.

Usually, the injectors have two pins. One pin is connected to the battery through the ignition relay and the other pin goes to the ECU. The ECU sends a pulsing ground to the injector, which closes the circuit, providing the injector's solenoid with current. The magnet on top of the plunger is attracted to the solenoid's magnetic field, opening the valve. Since there is high pressure in the rail, opening the valve sends fuel at a high velocity through the injector's spray tip. The duration that the valve is open- and consequently the amount of fuel sent into the cylinder- depends on the pulse width (i.e. how long the ECU sends the ground signal to the injector).

When the plunger rises, it opens a valve and the injector sends fuel through the spray tip and into either the intake manifold, just upstream of the intake valve, or directly into the cylinder. The former system is called multiport fuel injection and the latter is direct injection.

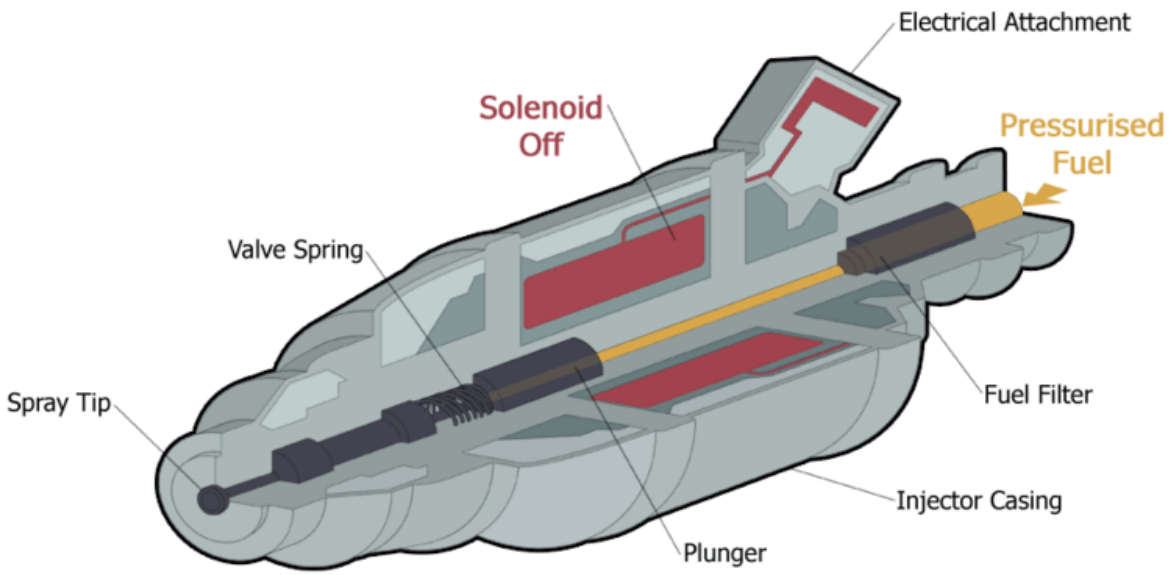

Figure 8.1: Fuel injector

8.2.2 Engine Throttle Working:

We've already looked at how electronic throttle control works. We showed you that, when a driver pushes his or her gas pedal, an accelerator pedal position sensor (APP) sends a signal to the ECU, which then commands the throttle to open. The ECU takes information from the throttle position sensor and APP until the throttle has reached the desired position set by the driver. But what happens next?

Either a mass air flow sensor (MAF) or a Manifold Absolute Pressor Sensor (MAP) determines how much air is entering the throttle body and sends the information to the ECU. The ECU uses the information to decide how much fuel to inject into the cylinders to keep the mixture stoichiometric. The computer continually uses the TPS to check the throttle's position and the MAF or MAP sensor to check how much air is flowing through the intake in order to adjust the pulse sent to the injectors, ensuring that the appropriate amount of fuel gets injected into the incoming air. In addition, the ECU uses the o2 sensors to figure out how much oxygen is in the exhaust. The oxygen content in the exhaust provides an indication of how well the fuel is burning. Between the MAF sensors and the 02 sensor, the computer fine-tunes the pulse that it sends to the injectors.

8.2.3 Controlling Idle:

Let's talk about idling. Most early fuel injected vehicles utilized a solenoid-based idle air control valve (IAC) to vary air flow into the engine during idle (see the white plug in the above image). Controlled by the ECU, the IAC bypasses the throttle valve and allows the computer to ensure smooth idle when the driver does not activate the accelerator pedal. The IAC is similar to a fuel injector in that they both alter fluid flow via a solenoid actuated pin.

Most new cars don't have IAC valves. With older cable-controlled throttles, the air entering the engine during idle had to go around the throttle plate. Today, that's not that case, as Electronic Throttle Control systems allow the ECU to open and close the butterfly valve via a stepper motor.

The ECU monitors the rotational speed of the engine via a crankshaft position sensor, which is commonly a Hall Effect sensor or optical sensor that reads the rotational speed of the crank pulley, engine flywheel, or the crankshaft itself. The ECU sends fuel to the engine based upon how fast the crankshaft rotates, which is directly related to the load on the engine. Let's say you turn on your air conditioning or shift your vehicle into drive. The speed of your crankshaft will decrease below the threshold speed set by the ECU due to the added load. The crankshaft position sensor will communicate this decreased engine speed to the ECU, which will then open the throttle more and send longer pulses to the injectors, adding more fuel to compensate for the increased engine load. This is the beauty of feedback control.

Why does your engine rev higher at startup? When you initially turn on the vehicle, the ECU checks the engine temperature via a coolant temperature sensor. If it notices that the engine is cold, it sets a higher idle threshold to warm the engine up.

Figure 8.2: EFI Idling

8.2.4 Controlling Ignition Timing:

Now that we've mentioned the ECU's tasks of maintaining engine idle speed, as well as maintaining a proper air/fuel mixture, let's talk about ignition timing. To achieve optimum operation, the spark plug must be provided with current at very precise moments, usually about 10 to 40 crankshaft degrees prior to top dead center depending on engine speed. The exact moment that the spark plug fires relative to the piston's position is optimized to facilitate the development of peak pressure. This allows the engine to recover a maximum amount of work from the expanding gas.

Older engines (up until the mid 2000s) used distributors to control spark. Shown above, this system consists of a rotor and a distributor cap. The rotor is electrically connected to the ignition coil, which is basically a transformer that steps 12v up to over 10,000 volts needed for spark. The rotor is mechanically connected to the camshaft via a gear. As the camshaft spins, so does the rotor. As the rotor spins, it comes very close to copper posts (one for each cylinder). The current from the ignition coil jumps the small air gap between the rotor and the posts, sending high voltage through spark plug wires, to each cylinder's spark plug at a specific time. Note that these systems needed a way to alter timing. At high engine speeds, advancing spark is necessary. Early engines with distributors used engine vacuum or rotating weights to adjust timing. Later, transistor-based timing systems became more common.

Modern vehicles don't use a centrally located ignition coil. Instead, these distributorless ignition systems (DIS) have a coil located on each individual spark plug. Based on input from the crankshaft position sensor, knock sensor, coolant temperature sensor, mass airflow sensor, throttle position sensor, and others, the ECU determines when to trigger a driver transistor, which then energizes the appropriate coil.

The ECU is able to monitor the piston's position via the crankshaft position sensor. The ECU continually receives information from the crankshaft position sensor and uses it to optimize spark timing. If the ECU receives information from the knock sensor (which is nothing more than a small microphone) that the engine has developed a knock (which is often caused by premature spark ignition), the ECU can retard ignition timing so as to alleviate the knock.

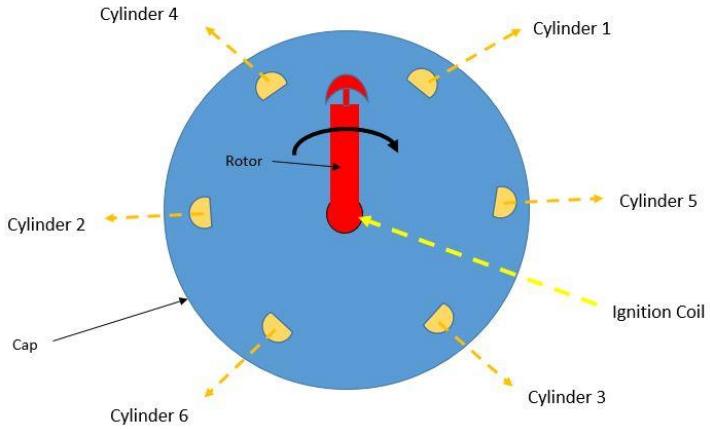

Figure 8.3: Cylinder and ignition Timing graph

8.2.5 Controlling Valve Timing:

The fourth major function of the ECU is to adjust valve timing. This applies to vehicles that utilize variable valve timing, which allows engines to achieve optimal efficiency at a multitude of engine speeds.

8.2.6 Lubricating System:

When it comes to day-to-day car maintenance, your first concern is probably the amount of gas in your car. How does the gas that you put in power the cylinders? The engine's fuel system pumps gas from the gas tank and mixes it with air so that the proper air/fuel mixture can flow into the cylinders. Fuel is delivered in three common ways: carburetion, port fuel injection and direct fuel injection.

- In carburetion, a device called a carburetor mixes gas into air as the air flows into the engine.

- In a fuel-injected engine, the right amount of fuel is injected individually into each cylinder either right above the intake valve (port fuel injection) or directly into the cylinder (direct fuel injection).

Oil also plays an important part. The lubrication system makes sure that every moving part in the engine gets oil so that it can move easily. The two main parts needing oil are the pistons (so they can slide easily in their cylinders) and any bearings that allow things like the crankshaft and camshafts to rotate freely. In most cars, oil is sucked out of the oil pan by the oil pump, run through the oil filter to remove any grit, and then squirted under high pressure onto bearings and the cylinder walls. The oil then trickles down into the sump, where it is collected again and the cycle repeats.

Now that you know about some of the stuff that you put *in* your car, let's look at some of the stuff that comes out of it. The exhaust system includes the exhaust pipe and the muffler. Without a muffler, what you would hear is the sound of thousands of small explosions coming out your tailpipe. A muffler dampens the sound. The exhaust system also includes a catalytic converter. See How Catalytic Converters Work for details.

The emission control system in modern cars consists of a catalytic converter, a collection of sensors and actuators, and a computer to monitor and adjust everything. For example, the catalytic converter uses a catalyst and oxygen to burn off any unused fuel and certain other chemicals in the exhaust. An oxygen sensor in the exhaust stream makes sure there is enough oxygen available for the catalyst to work and adjusts things if necessary.

Besides gas, what else powers your car? The electrical system consists of a battery and an alternator. The alternator is connected to the engine by a belt and generates electricity to recharge the battery. The battery makes 12-volt power available to everything in the car needing electricity (the ignition system, radio, headlights, windshield wipers, power windows and seats, computers, etc.) through the vehicle's wiring.

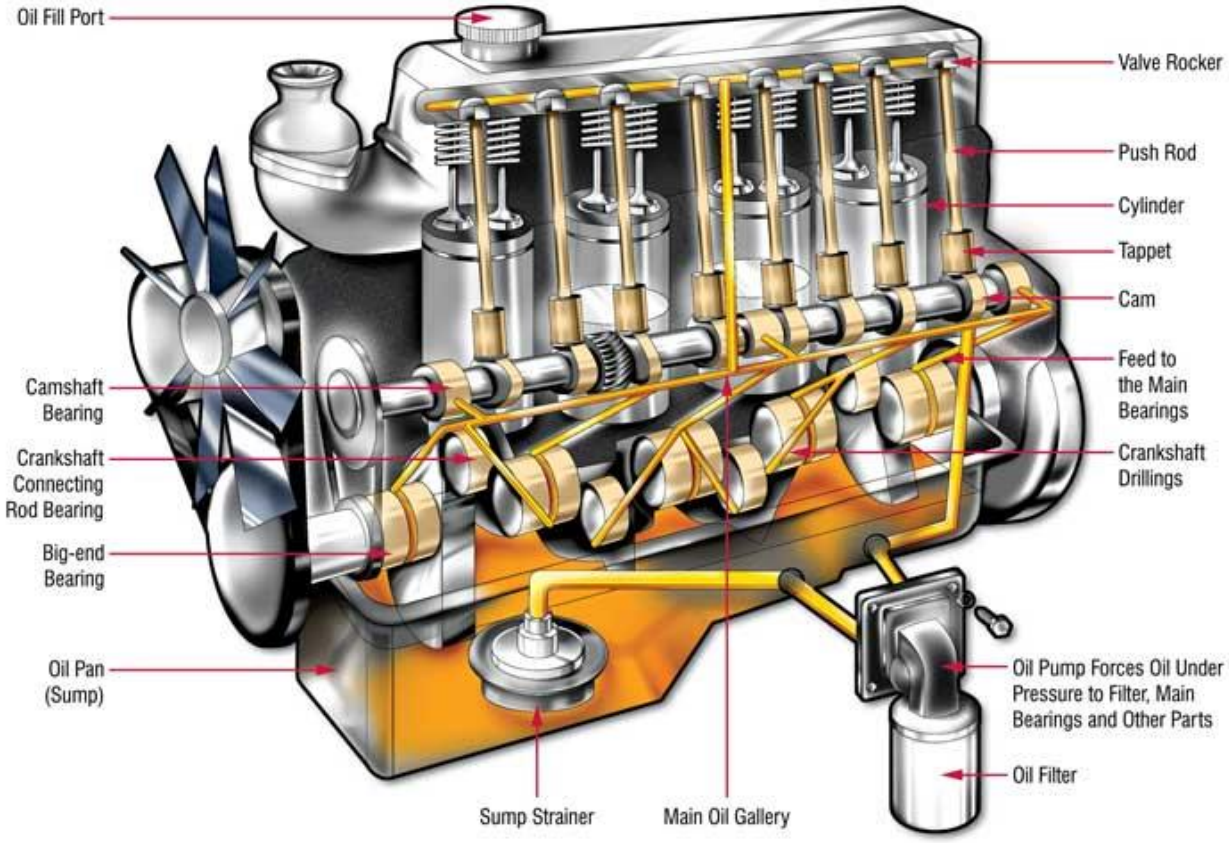

Figure 8.4: Lubricating System

8.3 PROCEDURE:

- The oil level in the engine is checked prior to starting the experiment and necessary precautions are taken.
- After the oil inspection the engine is started, if the engine does not start then preheating using glow plug may be required which is done by turning the key counter clockwise and holding for a few seconds.
- Now that the engine has started, we set a base engine speed (say 800 rpm), and proceed with our experiment.
- We note the corresponding values of oil pressure and oil temperature, given to us by sensors and dial connected to the engine apparatus, for given value of engine speed.
- Increase the engine speed with suitable increments and note corresponding values of oil temperature and pressure

8.4 OBSERVATIONS & CALCULATIONS:

Table 4:

Sr. #	Engine Speed 'rpm'	Time 'min'	Engine oil temperature, T_1 '^oC'	Oil pressure 'Psi'	Vaccum Gauge
1.					
2.					
3.					
4.					

GRAPH:

8.5 COMMENTS:

9. Lab Session 8

To Study working of Dual Fuel Engine.

9.1 OBJECTIVES:

- To understand about Dual Fuel Engine.
- Difference between LPG and Petrol.

9.2 THEORY:

9.2.1 Introduction:

LPG, also known as propane and auto-gas, is a by-product of crude oil extraction and the refining process. Many people who consider LPG as an alternative to petrol do so because they believe that the combustion of propane results in lower CO2 emissions. Unfortunately, the jury is still out on this matter. In fact, two recent studies found conflicting results in terms of the production of hydrocarbons from the combustion of LPG. The first found a significant increase of CO2 emissions compared to petrol, and the other showed a slight increase at a low engine load but a considerable decrease at a high engine load.

What is for certain is that LPG burns cleaner than petrol and therefore emissions of particulates is very low. Moreover, LPG is non-toxic, non-corrosive and free of tetra-ethyl lead and additives. It also has a high-octane rating (The **octane rating** is a measure of how likely a gasoline or liquid petroleum fuel is to self-ignite. The higher the number, the less likely an engine is to pre-ignite and suffer damage).

In terms of fuel costs, LPG costs a little more than half the price of petrol or diesel, but fuel economy is about 20-25% lower. Therefore, you can get much more bang for your buck or in vehicle parlance, more miles per gallon. According to the AA, overall running costs of an LPG car is approx. a third less than a petrol only car – but only once you've recovered the cost of the conversion.

The cost of converting an existing petrol car so it can run on petrol or LPG costs between £1,500 and £2,500. In order to make this investment worthwhile you will need to travel around 14,000 miles a year (i.e. if you have a typical delivery van then you are most likely doing about 20,000 miles p.a., LPG is therefore a good option to consider if you are trying to reduce your total life operating costs for the van).

From an insurance perspective, the AA advises that the installer should provide you with a registration receipt to show that the conversion has been done correctly. A copy of this will be required by your insurance company.

If you live in Europe (incl. the UK) you should also note that you can't take an LPG powered car through the Eurotunnel, even if the tank has been emptied or disconnected. There are also restrictions in some underground car parks here and in Europe.

In short, the benefits of LPG vs. petrol fuel cars are significant, but only make economic sense if you are running at high engine loads and doing at least 14,000 miles a year.

There are many other differences between these two engines except cost. These are as follow.

9.2.2 DIFFERENCE BETWEEN LPG VS PETROL ENGINE:

Sr. No.	Petrol Engine	LPG Engine
1.	Fuel Consumption in Petrol engine is less when compared to LPG.	Engine running on LPG results 10% increase in consumption compare to petrol engine.
2.	Petrol has odor or it smell badly.	LPG is odorless or it has no smell. But due to identified leakage Ethyl Mercaptan added in i which also smell badly.
3.	Octane rating of petrol is 81.	Octane rating of LPG is 110 which is more than petrol, so there is less possibility o detonation.
4.	Compare to LPG Engine, petrol engines are not smooth running.	Due to higher octane number less, knocking LPG engines are running smoothly compare to petrol engines.
5.	Lead is added in petrol engine to increase octane rating, which is harmful for environment.	LPG is lead free so it is ecofriendly.
6.	When petrol passes over the oil rings, it washes out the lubricant film from the upper cylinder surface. It causes lack of lubricant which increases wear and tear. So, the life of petrol engine is less compare to LPG engine.	LPG does not wash out lubricant film, hence the life of LPG engine is increased by 50%.
7.	It forms carbon deposit on the spark plugs, so the life of spark plug is shorter.	LPG does not deposit carbon on spark plug so the life of spark plug is more than petro engine.
8.	Carburetor is used to mix air fuel mixer in proper ratio in petrol engine.	Vaporizer used to mix air fuel in proper ratio in LPG engine. It reduces the LPG pressure vaporize it and supply it according to engine requirement.