# TRADE OF HEAVY VEHICLE MECHANIC

PHASE 2

**Module 6**

**Diesel Fuel System**

**UNIT: 1**

# Diesel Fuel System

# Table of Contents

# 1.0 Learning Outcome

**By the end of this unit each apprentice will be able to:**

- State the function and operation of a diesel fuel system and identify injector types
- Replace a fuel filter, test/replace fuel cut off solenoid and vent the fuel system
- Remove and test an injector, report on condition, adjust breaking pressure and fit new nozzle as necessary and refit to engine
- Dismantle a fuel lift pump, report on condition, inspect, reassemble and test
- Test correct operation of cold start devices

## 1.1 Key Learning Points

- Principle of operation of the compression ignition system
- Phases of combustion - combustion process - products of combustion and their effects on the environment explained
- Explaining direct, indirect injection and combustion chamber designs
- Interpretation of injector test results, and follow up action
- Methods of removing, testing, dismantling, reassembling and refitting injectors
- Function only of injection pump - inline, rotary, Pressure Timed (PT)
- Basic Introduction to Common Rail, Unit Injector and single solenoid controlled pump systems
- Hazards associated with the fuel system and precautions to be taken
- High pressure spray, hazards
- Fuel specification and standards
- Effects of air in fuel system and venting procedure
- Fuel conditioning and storage. Filters, water traps, fuel tank arrangement, capacity and filling methods
- Function and operation of fuel lift pump - diaphragm and plunger types
- Function and operation of fuel shut down systems Environmental considerations, dealing with spillages and fire hazards
- Maintenance of the fuel system

- Function, operation and types of fuel heaters
- Function, operation, construction, and testing of glow plug circuits and thermo start devices
- Interpretation of engine performance graphs

# 2.0 Health and Safety

If the proper safety procedures are not adhered when working on **Diesel Fuel Systems** this could lead to serious injury \health problems to personnel.

Instruction is given in the proper safety precautions applicable to working on **Diesel Fuel Systems** which include the following:

- Use of barrier cream or suitable gloves to prevent dermatitis
- Use of exhaust extractor
- Use of absorbent material for immediate treatment of diesel spillage
- Danger associated with high pressure fuel sprays
- Danger associated with spray mist when testing injectors (use of adequate extraction system)
- Hazards of system pressures when removing / replacing components
- Importance of cleanliness when dismantling fuel injection components etc.
- Use of correct type of fire extinguisher for diesel fuel fires
- Use of Personal Protective Equipment (PPE) e.g. Eye protection, foot wear etc.
- Safety issues associated with working on common rail diesel fuel injection and PD (Pump Duse) pump unit injection system ,awareness of high fuel pressures e.g. up to approx 2000 Bar. **Therefore it is imperative that manufacturer's recommended safety and precautionary procedures are adhered to, prior to and during all common rail / PD fuel system repairs**

Refer to motor risk assessments, Environmental policy, and Material Safety Data Sheets (MSDS).

# 3.0 Introduction

The difference between the petrol and diesel engine is the fuel they use for combustion. Petrol is a highly inflammable liquid which evaporates rapidly into a gas and can be ignited by a spark. Diesel is a low inflammable liquid which requires a lot of heat to ignite it, but it is cheaper to manufacture, and most importantly more fuel is produced from the same quantity of crude oil. To ignite the diesel fuel for combustion, the air that is drawn in on induction is compressed to a very high pressure. The temperature of the air will also rise at which point the fuel is injected into the cylinder and ignited by the hot air. This is called **COMPRESSION IGNITION** – the correct name for a diesel englne . The higher compression required to ignite the fuel, puts extra strain on the engine, as a result the diesel engine is a more robust construction and the precision made high pressure pump that is required to inject the fuel into the combustion chamber against the high compression makes the diesel engine more expensive to produce.

## Advantages of the Diesel Engine

1. Lower fuel consumption;
2. Longer intervals between overhauls due to the more robust construction.
3. Greater torque at lower r.p.m. which gives better top gear performance.

## Disadvantages of the Diesel Engine

1. High initial cost due to more robust built engine and precision made fuel injection equipment.
2. Less power-weight ratio which means lower acceleration speeds.
3. Noise due to high pressure injection pump and diesel knock.

## Compression Ignition Engine (C.I. engine)

Compression Ignition engines are used in most goods and passenger vehicles today. These engines are alternatively described as diesel engines in honour of Dr. Rudolph Diesel who pioneered and developed heavy engines of this type.

In general construction and arrangement of the four-stroke diesel or C.I. engine is very similar to the four-stroke, spark ignition engine. Similar components are used in both types of engine, the particular operating requirements of each being met by relatively small but important variations in design. The essential difference between the two types of engine lies in the way in which combustion is started and controlled. In the spark-ignition engine the compressed and turbulent mixture of air and vaporised petrol in the combution chamber is ignited by the electrical spark.

In the C.I. engine air only is subjected to much greater compression and turbulance, and after compression the temperature of the air usually exceeds 1000°C. This temperature is well above the self-ignition temperature of fuel oil (diesel) so that when an atomised spray of oil is forced into very hot, dense and turbulent air in the combustion chamber the burning starts spontaneously. The rate of combustion after ignition is controlled directly by the rate at which fuel oil is forced into the chamber, i.e. by how much fuel is injected.

The compression ratios of spark-ignition engines have been increased in recent years in order to obtain greater thermal efficiencies and better fuel economy. The normal maximum with readily available fuels is about 10:1. This being the reason of detonation which will occur with ratios above 10:1 unless special fuel is used.

The compression ratios of C.I. engines range from 14:1 up to 22:1. These high ratios are essential to the operation of the engine and their use is possible because air only — not a mixture of fuel and air is compressed. These higher compression pressures result in higher maximum cylinder pressures during combustion, which results in the C.I. engine having a higher thermal efficiency, this being about 35% as against 20-25% of the spark ignition engine.

## 3.1 Diesel Fuel

Like petrol, diesel is a compound of hydrogen and carbon, extracted from crude oil.


There are different grades of diesel fuel for diesel engines. What is commonly sold in a service station is highly refined, and is suitable for use in high-speed diesel engines, including those in light automotive use.

The cetane rating of a diesel fuel defines how easily the fuel will ignite when it is injected into the cylinder. The lower a fuel's cetane rating, the longer it takes to reach ignition point. Using a fuel with too low a cetane rating will increase the amount of diesel knock in an engine. When diesel fuel is injected into the cylinder, it does not ignite instantly. It takes time for the heat of the compressed air in the cylinder to heat the fuel sufficiently for it to ignite. This period of time from the start of injection, to the start of combustion is called the delay period. During this delay period, fuel continues to be injected into the cylinder.

When the fuel is heated sufficiently, it erupts into flame. Combustion occurs. The sudden pressure rise sends a shock wave through the combustion chamber that can be heard outside the engine. This is the sound called diesel knock. Diesel knock can also be caused by poor atomization of the fuel, which can take too long to reach combustion temperature. The higher the cetane rating of the fuel, the easier a cold engine will be to start. The engine will produce less smoke and odours, and there will be fewer deposits in the combustion chamber. Diesel engines are also required to operate in low temperatures. During low temperatures, the fuel becomes thicker. If the temperature is too low, paraffin's in the fuel begin to solidify, and form waxes. These waxes can block filters, causing fuel starvation, and low power output.

To help prevent this, filters are fitted close to the engine, and sometimes heaters are used. Diesel fuel also acts as a lubricant for the fuel system components - provided it is free of water and abrasive particles as these will destroy the high pressure system.

## Hazards with diesel fuel

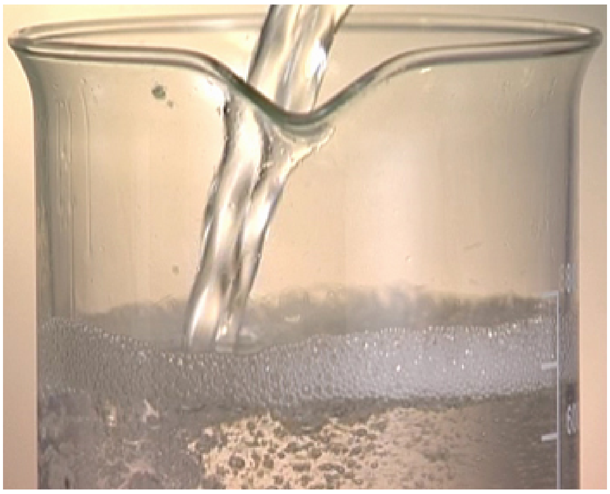
While diesel fuel oils are safer for storage and handling purposes than petrol, they do pose a bigger risk to skin disorders. For this reason it is advisable to use some barrier cream when working on diesel engines or its associated equipment i.e. pumps, injectors, filters, etc.

## 3.2 Diesel Fuel Requirements

Requirements of Diesel Fuel: The following qualities are required of diesel fuel:

- Ignitability: The ignition delay time must be short so that the engine will start easily. Diesel fuel must allow the engine to run quietly with little diesel knock.
- Cold fluidity: It must remain fluid under low temperature (no wax formation) so that the engine will start easily and run smoothly.
- Lubricating power: Diesel fuel also serves as a lubricant for the injection pump and nozzle. Therefore it must have adequate lubricating power.
- Viscosity: It must have a proper viscosity (thickness) so that it will be sprayed properly by the injectors.
- Sulphur content: Sulphur corrodes and wears engine parts so the sulphur content in diesel fuel must be minimal.
- Stability: No changes in quality may occur, and no gum, etc., may form in it during storage.

**NOTE: The fuel quality needed in this context is its ability to self-ignite, i.e. the temperature at which it will spontaneously ignite. At this stage it should be pointed out that the self-ignition temperature is NOT the flash point. The flash point of a fuel is the lowest temperature at which the fuel gives off a vapour that will flash when exposed to a naked flame. (Flash point for diesel fuel is about 70°C whereas the self ignition temperature is in the region of 400 °C.)**



- **Cetane Rating (Cetane Index)**: Classification of fuels for diesel engines. This compares the ignition quality of a fuel with two reference fuels.
- **Reference Fuels:**
    1. Cetane – given the value of 100 because of its good ignition quality. Alpha-methyl naphthalene rated at zero because of its very poor ignition quality.
    2. A fuel rated at 55 has a similar ability to self ignite as a fuel consisting of 55% Cetane and 45% alpha-methylnaphthalene by volume. The range of cetane indices for diesel oil is from 30 to 55, marked gas oil in Ireland has a minimum value of 45 and road diesel has a minimum value of 50.

The fuel used in a diesel engine should have a Cetane number or rating just high enough to give freedom from pronounced knock for the particular engine under consideration.

# 4.0 Design and Operation of the Diesel (CI) Engine

## 4.1 Four-Stroke Diesel Engine Cycle

A 4-stroke diesel engine has a cycle of 4 strokes. A stroke is the distance from top dead centre to bottom dead centre. The piston travels down for 1 stroke on intake, up for compression, down for power, and back up for exhaust.

In intake, or induction, the inlet valve opens and the piston starts to move down from top dead centre. Air enters the cylinder through the inlet port. When the piston reaches bottom dead centre, the cylinder is full of air. The inlet valve closes.

The piston starts up from bottom dead centre. The exhaust valve is closed so the cylinder is sealed. The piston's upward motion compresses the air. When the piston reaches top dead centre, the air is compressed to about one-sixteenth of its original volume. This is higher compression than in a similar petrol engine. Compressing the air also heats it.

Both valves stay closed as the piston rises. Just before it reaches top dead centre, an injector sprays fuel into the chamber. It mixes with the very hot compressed air and ignites.

**Air temperature of 400°c is required to ignite the diesel fuel.**

Combustion occurs, the temperature rises much higher and the gases expand and force the piston down in a power stroke. The piston reaches bottom dead centre, the exhaust valve opens.

With the exhaust valve open and inlet valve closed, the piston moves up, forcing exhaust gases out of the exhaust port. The piston reaches top dead centre, the exhaust valve closes, the inlet valve opens and the cycle starts again.

## 4.2 Basic Four Stroke Diesel Principles

This is one cylinder of a 4-stroke diesel engine. This model uses what is called direct injection. It is an internal combustion engine, with the 5 events common to all internal combustion engines. Unlike the petrol engine, air alone enters the cylinder on the intake stroke. The fuel is controlled by the driver.

Compression forces the air into a small volume. This compression heats the air. At the end of this stroke, diesel engine fuel is injected into the combustion chamber.

Ignition, burning the mixture. It is just the heat of the compressed air that ignites the fuel. That's why diesels are called compression ignition engines.

Power, where energy released from combustion generates the force to turn the crankshaft. And Exhaust, removing left-over gases. This brings the system back to where it began, ready for another cycle.

One can obtain diesel from petroleum, which is called **petrodiesel** to distinguish it from diesel obtained from other sources. As a hydrocarbon mixture, it is obtained in the fractional distillation of crude oil between 250°C and 350°C at atmospheric pressure. Diesel is generally simpler to refine than gasoline and often costs less (though price fluctuations often mean that the inverse is true). However, diesel fuel often contains higher quantities of mineral compounds and sulfur. Emission standards in Europe have forced oil refineries to dramatically reduce the level of these impurities, resulting in a much cleaner-burning fuel that produces less soot. The United States has worked to reduce the emissions from gasoline-powered vehicles in the last few decades, but diesel engines have not been regulated as heavily. Diesel fuel in the U.S. is generally much less pure than European diesel, though the transition to ultra-low sulfur diesel (ULSD) will begin in 2006.

Reducing the level of sulfur in diesel is better for the environment, and it allows the use of more advanced catalytic converters to reduce emissions of oxides of nitrogen (NOx). However, this also reduces the lubricity of the fuel, meaning that additives must be put into the fuel to help lubricate engines.

Diesel contains approximately 18% more energy per unit of volume than gasoline, which along with the greater efficiency of diesel engines contributes to fuel economy (distance traveled per volume of fuel consumed).

- Gas Oil - slightly less refined than Diesel for road usage.
- MDO (Marine Diesel Oil) - Thin Diesel, less refined than Gas Oil.
- IFO (Intermediate Fuel Oil)
- MFO (Medium Fuel Oil) - A mixture of HFO and MDO
- HFO (Heavy Fuel Oil) - Thick, viscous dark brown gunk. Requires heating to flow.

### Biodiesel

Biodiesel can be obtained from vegetable oil and animal fats (bio-lipids, using transesterification). Biodiesel is a non-fossil fuel alternative to petrodiesel. It can also be mixed with petrodiesel in any amount in modern engines, though it is a strong solvent and can cause problems in some cases. A small percentage of biodiesel can be used as an additive in low-sulfur formulations of diesel to increase lubricating ability.

### Uses

Diesel is identical to heating oil, used in central heating. In both Europe and the United States taxes on diesel fuel are higher than on heating oil, and in those areas, heating oil is marked with a red dye and trace chemicals to prevent and detect tax fraud.

Diesel is used in diesel engines (cars, boats, motorbikes...), a type of internal combustion engine. Rudolf Diesel originally designed the diesel engine to use coal dust as a fuel, but oil proved more effective.

The first diesel-engine automobile trip was completed on January 6, 1930. The trip was from Indianapolis to New York City - a distance of nearly 800 miles. This feat helped to prove the usefulness of the internal combustion diesel engine.

## *4.3 Diesel Combustion Chambers*

Diesel combustion chambers come in 2 main types. Direct and indirect injection. Both are designed to promote turbulence, to help the compressed air and injected fuel mix well.

Engines using direct injection have cylinder heads with a flat face. The combustion chamber is formed in the top of the piston. Sometimes, the rim of the piston provides “squish”, forcing the air to the centre of the combustion chamber. This causes turbulence as fuel is injected into the cylinder.

In indirect injection, the piston is fairly flat, or has a shallow cavity. The main combustion chamber is between the cylinder head and the top of the piston, but a smaller, separate chamber is in the head. Fuel is injected into this smaller chamber. It can have various designs. A swirl chamber is spherical, and connected to the main chamber by an angled passage. Both the injector and glow plug are screwed into the head. The glow plug preheats the air inside to help start the engine.

During compression, the spherical shape makes the air swirl in the chamber. This helps make a better mixture of the air and fuel, which improves combustion. This combustion chamber is divided into a main combustion chamber and an air cell, joined by a throat. The injector is in the throat.

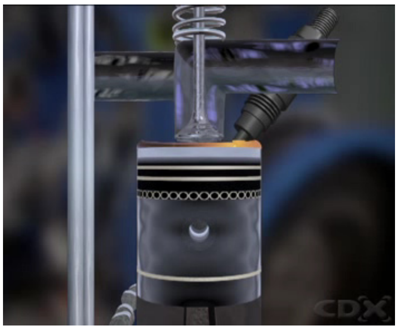
When injection commences, combustion pressure forces the air to flow from the air cell where it mixes with fuel from the injector. The rush of air from the air cell produces a rotary motion of gas in the main chamber which helps make combustion more efficient. This pre-combustion chamber is screwed into the cylinder head. The injector is mounted in the upper end. Injection occurs near the top of the compression stroke. Only part of the fuel is burned in the pre-combustion chamber because of the limited amount of air there. The high rise in pressure forces burning fuel into the main chamber. This happens very rapidly, which helps make more efficient combustion.

The compression ratio of a diesel engine is much higher than that of petrol one. typical value of diesel engine 18:1

**Refer to automotive technical manuals for specific engine compression ratios.**

## 4.4 Diesel Fuel Delivery

Different diesel engines use different fuels. Fuel can be delivered to the chamber in different ways. **Direct injection** means fuel is injected directly into the chamber. The cylinder head usually has a flat surface and the combustion chamber is formed in the piston crown. At top dead centre, there is very little clearance between the cylinder head and the top of the piston.



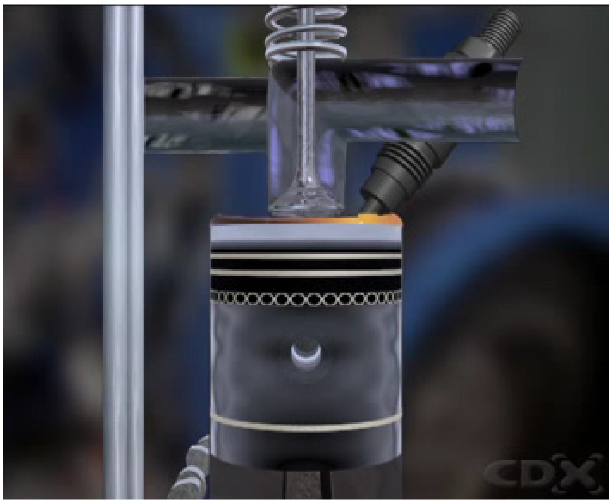
**This is a picture of a direct injection engine cylinder.**

Another method of injecting fuel is indirect injection. Fuel is sprayed into a smaller, separate chamber in the cylinder head. This chamber can have various designs. A glow plug is not a spark plug. It is a small electric heater that pre-heats the separate chamber as an aid to cold starting. It helps the combustion which then spreads to the main chamber.

**This picture is of an indirect injection engine cylinder.**

## 4.5 Direct Injection

Direct injection is usually used for larger diesel engines and 2-stroke diesel engines, while indirect injection is usually used for smaller 4-stroke diesel engines.

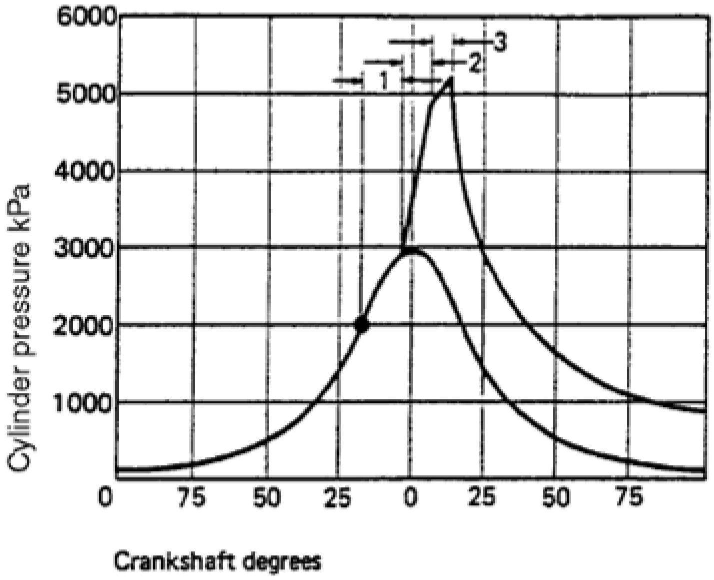


In a 4-stroke diesel, just as in a petrol engine, the inlet and exhaust ports are controlled by valves. But the much higher operating pressures and temperatures in diesel engines put more stress on diesel valves which are usually larger than those in petrol engines. The intake valve passes only air so it is cooler than the exhaust valve which releases all the hot gases after combustion.

Valves in the diesel engine are usually parallel to the centre-line of the engine. Small 4-stroke engines usually have 2 valves per cylinder. 1 inlet and 1 exhaust.

## 4.6 Three Phases of Combustion

The combustion process in the cylinder of a CI engine is usually described in three phases. The graph shows the variations in cylinder pressure plotted on a continuous crank angle base.




*Phases of combustion.*

The graph shows the variations in cylinder pressure plotted on a continuous crank angle base.

**Phase 1:** Ignition delay period. This is the time taken (or angle turned by the crank) between the start of injection to the commencement of the pressure rise. During this important period, the injected fuel particles are being heated by the hot air to the temperature required for the fuel to self-ignite.

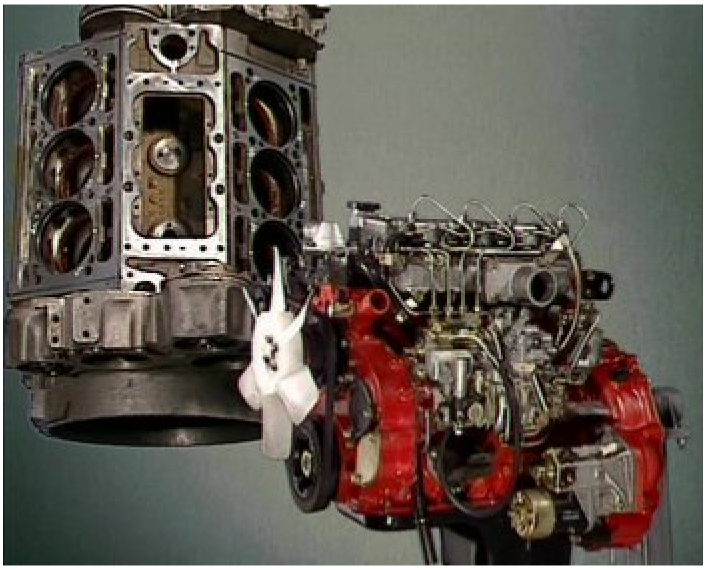
**Phase 2:** Flame spread causes a sharp pressure rise due to the sudden combustion of the fuel that was injected during the first phase. The rate of pressure rise governs the extent of the combustion knock. This is commonly called **'diesel knock'** and is considered to be the main disadvantage of the CI engine.

**Phase 3:** Direct burning of the fuel as it enters the chamber gives a more gradual pressure rise. When the engine is operating at less than full load, this phase does not exist.

# 5.0 Diesel Engine Components

4-stroke and 2-stroke diesel engines both use the principles of internal combustion, so many of their components have similar designs.

Diesel engine components are exposed to higher operating temperatures, pressures and forces than petrol engines of similar size. Therefore the cooling system has to dissipate the heat quicker than that of a petrol engine to maintain the correct operating temperature. Their compression ratios are higher, and they are often designed to out-last petrol engines. Their engine parts are usually heavier or more rugged than those of similar output petrol engines.



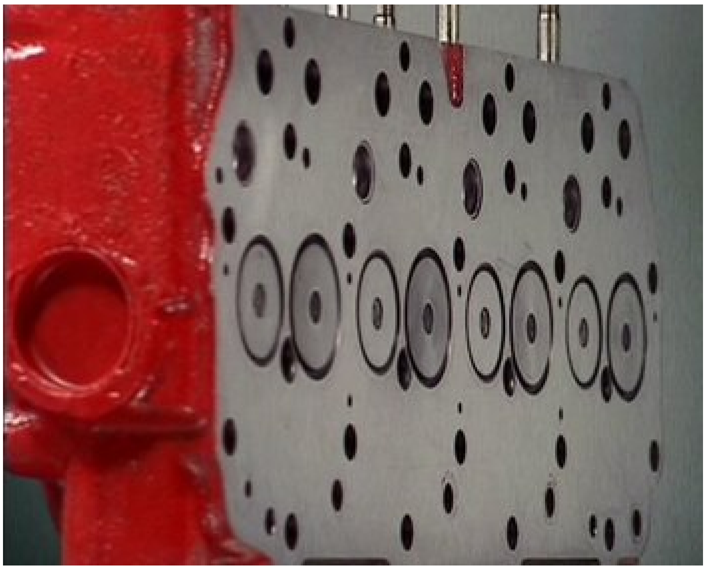
Diesel blocks are usually made of cast iron, and heavier than in a petrol engine. The skirt of the block usually extends below the centreline of the crankshaft. This adds strength and rigidity.

Machined into it are the cylinders which are usually in the form of detachable sleeves or liners. It is sealed at one end by a deep-section piece of metal or alloy called a cylinder head, which houses the valves and injectors.

Most cylinder heads in diesel engines are cast iron. Depending on the engine design, single or multiple heads can be used. Multiple heads avoid large castings that, apart from being heavy, are liable to distortion.

## 5.1 Diesel Engine Passages

Both 4-stroke and 2-stroke diesel engines have passages cast in the head to carry oil for lubrication and water for cooling.



The combustion chamber can be formed in the cylinder head or the piston crown. These chambers are different from those in petrol engines. That's because diesel fuel is different from petrol and so is the way it is ignited.

In a petrol engine, fuel already mixed with air enters the cylinder, and a spark plug ignites it. That's why petrol engines are called spark-ignition engines.

In a diesel engine, just air enters the combustion chamber first. It is then highly compressed, and its temperature rises. Fuel is injected. It ignites, due to heat of the compressed air. That's why diesels are called compression-ignition engines.

Injectors are mounted in the cylinder head so that they reach into the combustion chamber. They inject fuel into the chamber in atomised form - in a fine spray. Atomised fuel burns more efficiently than liquid fuel. Different spray patterns are used, depending on the shape of the combustion chamber.

## 5.2 Diesel Crankshaft

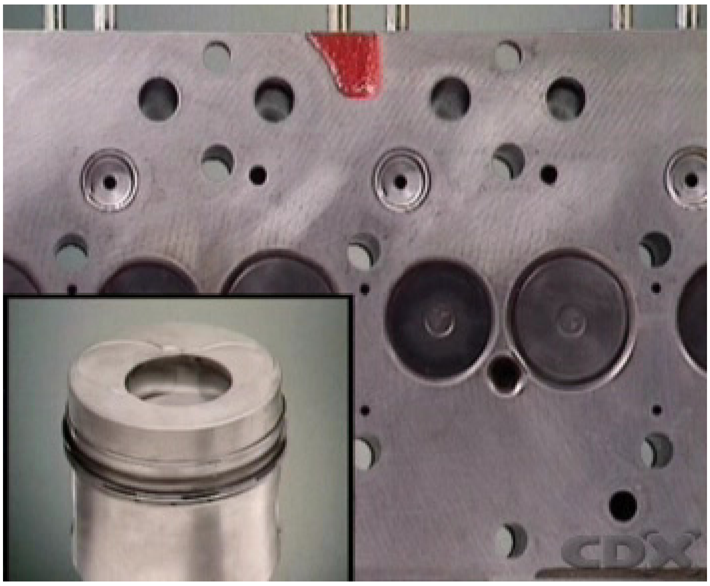
The crankshaft is the same on 4-stroke diesel engines and 2-stroke diesel engines. The shape may appear unusual at first. Crankshaft counterweights keep the rotating components in balance and help the crankshaft turn as smoothly as possible. The crankshaft turns because of the forces transmitted through the connecting rods. It must also be held in place. Different kinds of bearings have different designs. They reduce friction, and allow free movement.

The Crankshaft is held in the engine block by main bearings at points called journals. The crankshaft also needs to be located to stop lateral movement. This is done here by using flanges. Between the connecting rod and the crankshaft are connecting rod bearings. They protect the spinning crankshaft at points called journals. On the rear of the crankshaft of both the 4-stroke & 2-stroke diesel is a heavy flywheel.

It stores energy from the power stroke and gives it to the crankshaft to help it keep turning. In a 4-stroke, only 1 stroke in 4 delivers power. The energy from this 1 power stroke has to turn the crankshaft through the other 3 strokes. Without a flywheel the crankshaft would slow down and stop.

## 5.3 Diesel Engine Pistons

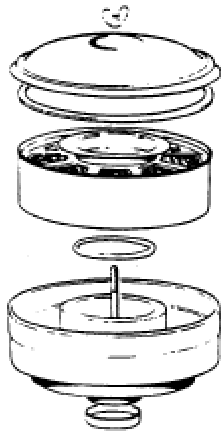
Pistons in 2 & 4-stroke diesel engines can change direction hundreds of times a second and are exposed to extremes of heat and pressure. Modern pistons are made of aluminium alloys. Diesels using direct injection have an almost flat surface on the cylinder head and almost all of the combustion chamber is in the head of the piston. Engines with indirect injection usually have pistons with a flatter head, and sometimes with small indentations.




When the piston is fitted, there must not be too much clearance. It has to seal in the high pressures and temperatures generated by combustion. This is done by piston rings – held in grooves in the side of the piston. The top two are called compression rings. The lower ring is an oil control ring. It scrapes excess oil off the lower cylinder walls.

## 5.4 Air filter

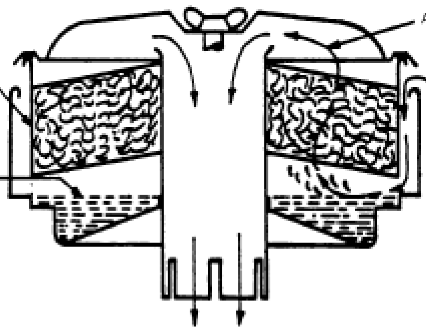
The most common type of air cleaner on diesel engines is the oil bath type. It has the advantage that it can be cleaned regularly without replacement. How regularly it is cleaned depends on the conditions in which the vehicle is operating (dusty etc).



*Air cleaner—wet type*

### Construction:

The filter assembly consists of a bowl which clamps to the manifold and is filled with oil to a specified level, inside the bowl is a wire mesh enclosed in a case with 13mm (approx) clearance at the side to allow the air to enter, and 13mm (approx) between the mesh and the oil. A cover is placed on top to seal the air from entering the manifold without passing through the filter.



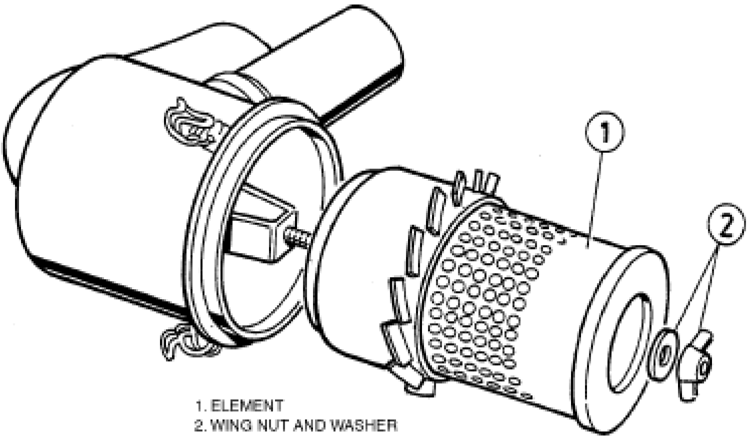
## Operating Principle:

When the engine is rotating the air is drawn in between the bowl and the case of the wire mesh and it turns sharply to pass up through the wire mesh. Because of the speed of the air, when it turns, the centrifugal force makes the dirt, which is heavier than the air contact the oil were it is trapped. Any small particles of dirt to escape the oil are trapped in the wire mesh which is moist with oil, so only clean air enters the manifold.

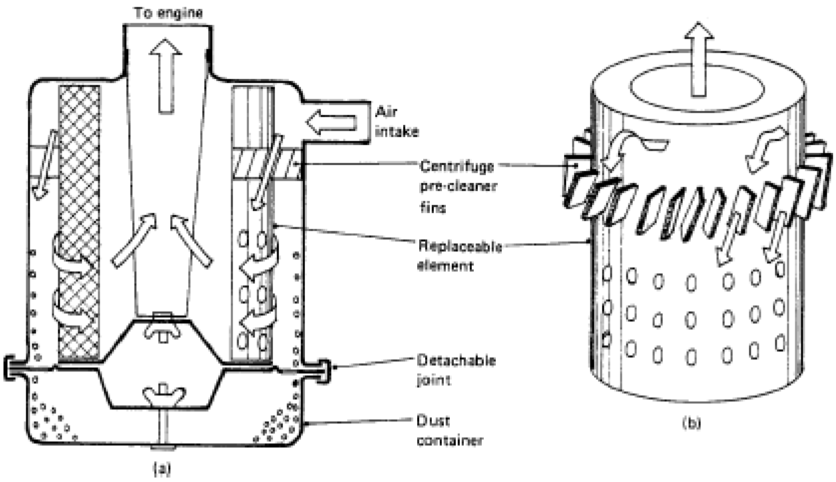
A blocked air cleaner will result in black smoke being emmited from the exhaust.

**NOTE:** It is most important that the oil in the bowl is at the correct level. To much oil will result in the engine drawing in the oil with the air and "running away". In service, the wire mesh should be cleaned with a cleaning fluid thoroughly, dipped in oil and allow to drain for a few hours (excessive oil in the mesh will result in the engine "running away".)

## Paper element type air cleaner




1. ELEMENT
2. WING NUT AND WASHER



## Medium-duty dry air cleaner

This type of cleaner consists of a removable cover attached to the air cleaner body which contains a replaceable paper filter element, with a row of plastic fins wrapped round it at the top end.

Air entering the upper part of the casing is directed to the fins on the element which give the air a high rotational speed on its way down between the casing and element. This will separate a large proportion of dirt from the air by centrifugal action.

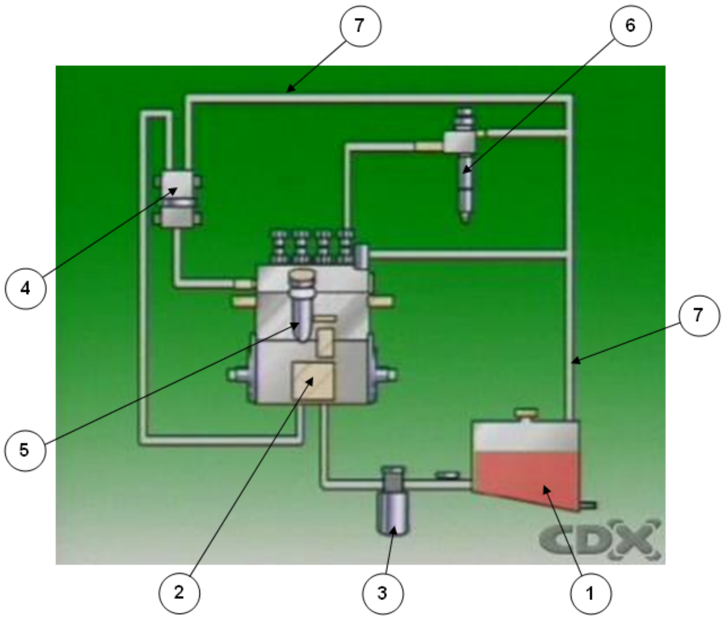
This dirt will be thrown to the outside, where it flows down the inner wall of the casing and is ejected into the dust cup or container, which is baffled to prevent the re-entry of the dust. The pre-cleaned air then passes through the paper filter, which removes any remaining dust, before it enters the engine.

The dust container may be removed periodically and cleaned. The paper elements should be replaced every 50,000 km when operating under normal conditions.

# 6.0 Diesel Fuel Supply Components

## 6.1 Diesel Fuel Injection

All diesel engines draw air only, past the intake valve into the cylinder. A high pressure fuel injection system injects fuel into the cylinder. The amount of fuel injected is varied to suit the load on the engine, and to control engine speed. Intake air volume does not change.




In a basic diesel fuel system

1. A fuel tank holds the diesel fuel.
2. A lift pump takes fuel from the tank. It keeps the injection pump full of fuel.
3. A sedimenter removes any water, and larger particles in the fuel.
4. A fuel filter removes minute particles.
5. An injection pump delivers fuel under very high pressure to the injectors, along injector pipes. It must send the correct amount of fuel, and it must send it at the correct time in the engine cycle. It also has a governor that controls engine speed and a control lever on the governor is connected to the accelerator pedal.
6. An injector, at each cylinder, sprays fuel into each combustion chamber.
7. Leak off pipes take fuel used for cooling, and for lubrication, from the injection pump and injectors back to the tank. They also help to remove air from the system.

The basic system is divided into 2 sections. Low and high pressure.

1. **Low pressure side.**

The low pressure side cleans the fuel and delivers it to the high pressure side, or fuel injection system. Dirt and water will damage a diesel fuel injection system. The highly polished components need a very efficient filtration system to ensure all traces of dirt and water are removed. The highly polished finish is achieved by lapping 2 components together to form a matched set. Matched components must not be interchanged after lapping is completed.

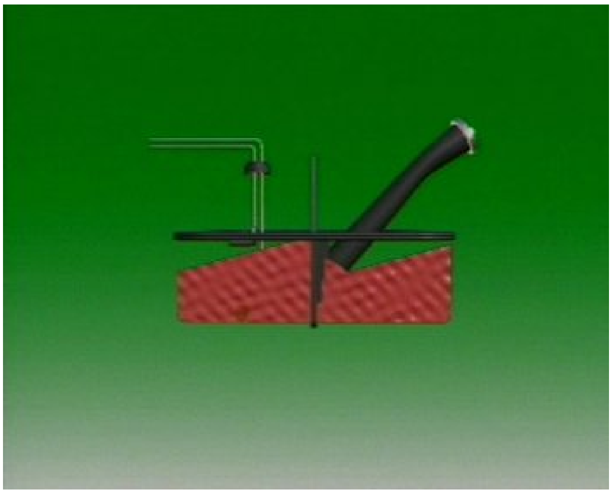
2. **High pressure side.**

The high pressure side of fuel injection system must raise the pressure of the fuel high enough to open an injector. This allows the fuel to be forced into the combustion chamber at the correct time.

## 6.2 Diesel Tanks & Lines

The fuel tank stores fuel in a convenient location, away from the engine. It is commonly made of steel or aluminium. Baffles ensure the pickup tube is always submerged in fuel. This stops air entering the system. The inside of the tank can be treated to prevent rust. Galvanizing must never be used, because diesel fuel reacts with zinc to produce powdery flakes that can block fuel filters. A diesel fuel tank should be kept full, to prevent water condensing on tank surfaces and contaminating the fuel.

In light commercial diesel engines, two fuel lines are used. One carries fuel from the tank to the filters, and then to the fuel injection pump. The other is the return line. It carries back to the tank the fuel that is used for lubricating and cooling the injectors, the injector pump, and for bleeding the filters.



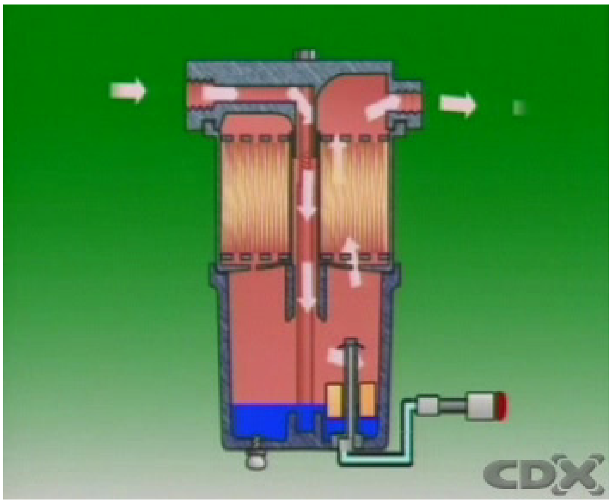
They are usually made of seamless steel tubing, coated with tin to prevent rust. Sometimes cadmium is used instead of tin. A fuel line must be large enough to provide enough fuel flow for maximum power.

It's supported under the vehicle by nylon insulators in brackets. Reinforced synthetic rubber hoses allow for movement, and vibration of components. The reinforcement is needed because the fuel line is subject to variations in pressure.

Injector pipes are made of cold-drawn, annealed, seamless steel tubing. The bore of the pipe is kept to the smallest diameter possible, and all of the pipes are the same length. If pipes of different lengths were used, it would affect injection timing.

## 6.3 Diesel Fuel Filters

The fuel filter removes abrasive particles, and water, that could damage the accurately-sized, and polished injection equipment. The most efficient filtering system uses the first filter to remove larger particles, and subsequent filters to remove smaller particles. Water traps and sedimenters trap water, and larger dirt particles. They can be separate units, or combined with an impregnated paper element filter this type of filter is called an agglomerator.



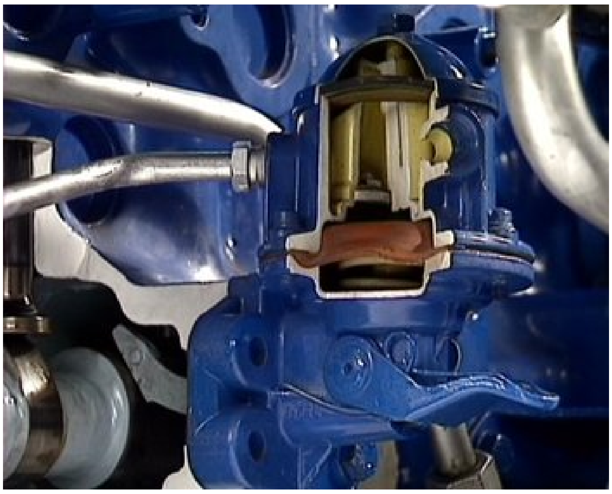

Separate units pass the incoming fuel over an inverted funnel. At the edge of the funnel, the fuel changes direction very quickly. Water and dirt are heavier than fuel, so they are trapped, away from the funnel edge. They fall under gravity, and settle at the base of the sedimenter. The lower housing is usually clear for easy inspection, and it can include a drain plug so sediment can be drained off daily.

The most common type of filter material in light diesel vehicles is resin-impregnated paper, pleated to offer a large surface area to the fuel. These filters are also considered the most efficient. In some of the filters that use this paper, fuel flows from outside to inside. In others, it flows from the base to the top or visa versa.

A water level switch can activate a light on the dash, to warn the operator, the sedimenter chamber may need draining. The switch has a float that is lighter than water, but heavier than fuel. In the float is a magnet. As the float rises on the water level in the fuel, the magnet closes a reed switch, which turns on a warning light in the instrument cluster. The operator can then remove the drain plug to drain the water.

## 6.4 Lift Pump

The lift pump transfers fuel from the tank to the fuel injection system. In modern vehicles, the tank is mounted below the engine, and the fuel has to be lifted up to the level of the engine. 3 types of lift pump are common on light vehicle diesel engines – the diaphragm-type pump, the plunger pump, and the vane pump.



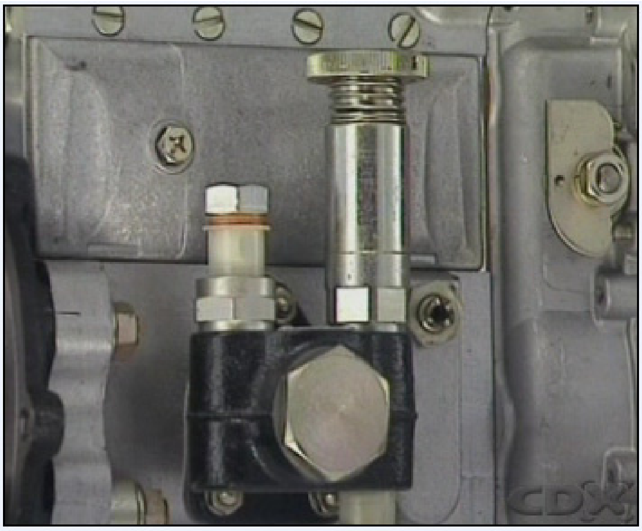
The diaphragm-type pump can be mounted on the engine, or on the injection pump. It is fitted with inlet and outlet valves, and an eccentric on a camshaft acts on a 2-piece rocker arm connected to a diaphragm. Rotating the eccentric causes the rocker arm to pivot on its pin, and pull the diaphragm down. This compresses the diaphragm return spring, and increases the volume in the pumping chamber above the diaphragm.

Atmospheric pressure at the fuel tank forces fuel along the fuel line, to open the inlet valve. Fuel flows into the pumping chamber. The eccentric keeps rotating, and the rocker arm is released. The spring exerts force on the diaphragm, to pressurize the fuel in the chamber. This pressure closes the inlet valve, and opens the outlet valve, letting fuel be delivered to the injection system.

If the system doesn't need all of the fuel delivered, the pressure in the outlet fuel line rises to the same level as in the pumping chamber. That holds down the diaphragm, and keeps the diaphragm return spring compressed. When this occurs, the split-linkage in the rocker arm, allows the lever to maintain contact with the eccentric, without acting on the diaphragm pull-rod.

## 6.5 Plunger Pump

A second type of lift pump in light vehicle applications is the plunger pump. It is mounted on the in-line injection pump, and it's driven by a cam inside the in-line injection pump housing.



Internally, a spring-loaded cam-follower converts the rotary motion of the camshaft into reciprocating motion. The reciprocating motion is transferred to a spring-loaded plunger, fitted with close tolerance in a cylindrical bore. It has 2 spring-loaded check valves - an inlet valve, and an outlet valve.

As the engine drives the injection pump, the lobe of the camshaft pushes the cam follower into the plunger pump. The cam follower acts directly on the plunger, pushing it towards the end of the cylinder bore. Fuel is displaced from one side of the plunger, through the outlet check valve, to the other side of the plunger.

When the cam follower retracts, spring force on the plunger moves the plunger out of the cylindrical bore. Fuel from the fuel tank enters behind the plunger through the inlet check valve. Fuel in front of the plunger is displaced out of the pump to the fuel injection system.

If the quantity of fuel required is reduced, so is the movement of the plunger.

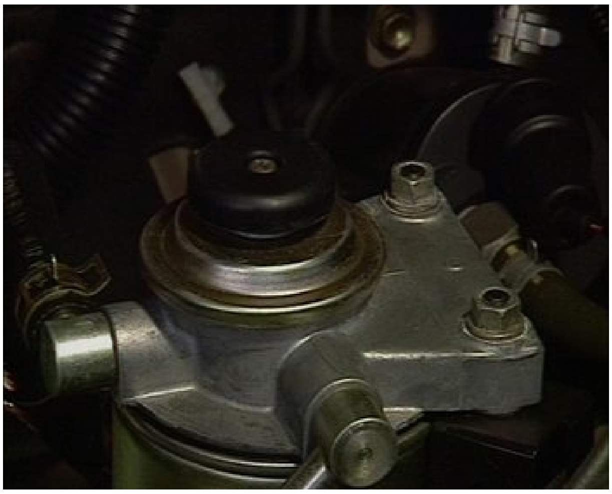
A vane pump is used in distributor type injection pumps. It is also known as a transfer pump. It is mounted on the input shaft in distributor type injection, and pumps fuel whenever the distributor pump is driven by the engine.

It consists of a rotor, mounted off-centre in pump housing. Slots are machined in the rotor to carry vanes. As the rotor rotates, the vanes can move into, and out of, the slots. The vanes seal on the edges of the rotor slots and the pump housing.

As the pump rotor rotates, trapped fuel is carried around by the action of the rotor, until the leading vane uncovers the outlet port. Since the rotor is offset, as it turns further, the volume between the vanes reduces, and fuel is squeezed out of the pump. A pressure relief valve controls the pump's operating pressure.

## 6.6 Priming Pump

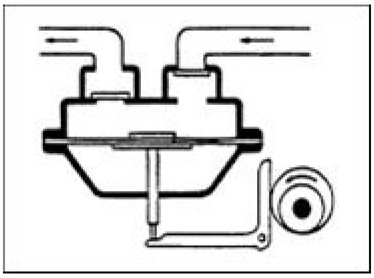
All diesel engines in light vehicle applications have a priming lever on the lift pump, or a separate priming pump to allow for removing air from the fuel system. This is called bleeding, or priming. Air can enter the system during filter replacement, or when a fuel line is disconnected. This air will prevent fuel from being injected, as air will compress and not pass through the fuel pipes therefore the fuel has to be removed from the system. Without a priming facility, the start motor would have to crank the engine over, to bleed and prime the system. Excessive use of the starter motor for this purpose would damage it, and it would soon discharge the battery.



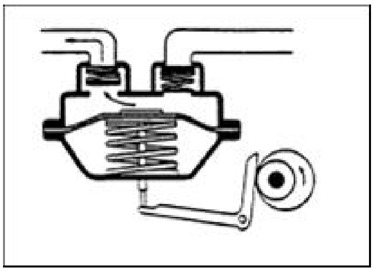
This diaphragm lift pump has a lever that acts on the diaphragm rocker arm. Moving the priming lever moves the diaphragm down. Releasing the lever allows the diaphragm return spring to force the diaphragm up. The action of the diaphragm and valves during bleeding is the same for normal operation of the pump.

## 6.7 Mechanical fuel pump - (Lift Pump) — Diaphragm type

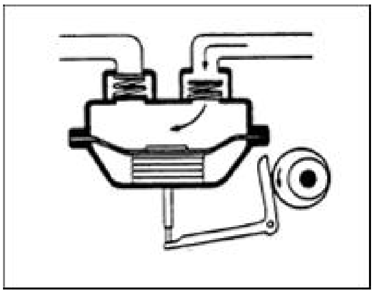
This consists of a chamber which is divided by a flexible partition (diaphragm). A rod which is fitted to one side of the diaphragm is operated by a lever from a cam on the camshaft. In one half of the chamber are two valves, the inlet valve through which diesel is drawn into the pump and the outlet valve through which diesel is pumped to the injection pump via the fuel filters.



In the other half of the chamber is a spring which controls the pump pressure, pushes the diaphragm upwards and keeps the lever on the camshaft. When the diaphragm is pushed upwards by the spring the pressure opens the outlet valve and closes the inlet valve.



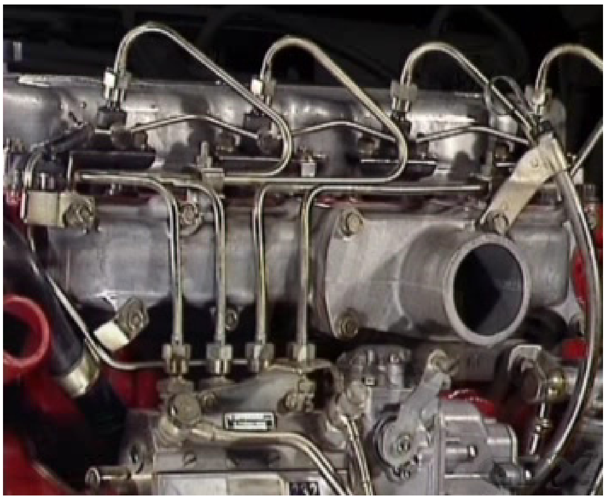
As the cam rotates, the lever and the diaphragm are pulled downwards and suction is created in the chamber. This suction closes the outlet valve and opens the inlet valve causing diesel to be drawn from the tank into the chamber. The operation is then repeated.



# 7.0 Diesel Fuel Injection High Pressure Components

## *7.1 High Pressure Components*

A light-automotive diesel engine typically has a higher compression ratio than a comparable petrol engine. This high compression ratio heats the air in the combustion chamber to a temperature high enough to ignite the fuel when it is injected. High injection pressures are needed to overcome the compression and combustion pressures in the combustion chamber, and break up the fuel into small particles.



Because of these high pressures, the injector pump and the injector are made from highly polished and accurately-sized components. The injector pump can be an in-line type, and it is driven by the engine or it can be a rotary type, also driven by the engine.

The quantity of air taken in on the intake stroke is not controlled by the driver. The driver controls how much fuel is delivered to the engine. A characteristic of all diesel engines is that at a fixed fuel setting, the amount of fuel delivered to the engine will increase as engine speed, and pump speed increases. This is called the rising characteristic of the fuel injection system, and unless it is controlled, over-speeding of the engine will results also because combustion pressures are greater in a diesel engine than in a comparable petrol engine, the components are stronger and heavier. The higher mass of these reciprocating and rotating components needs to be controlled, or damaging forces could be generated.

To achieve this control, all diesel engines use a governor to control how much fuel is delivered from the injection pump, to the injectors, and into the engine. There are several types of governors. Some operate mechanically, some are pneumatic, and some are hydraulic.

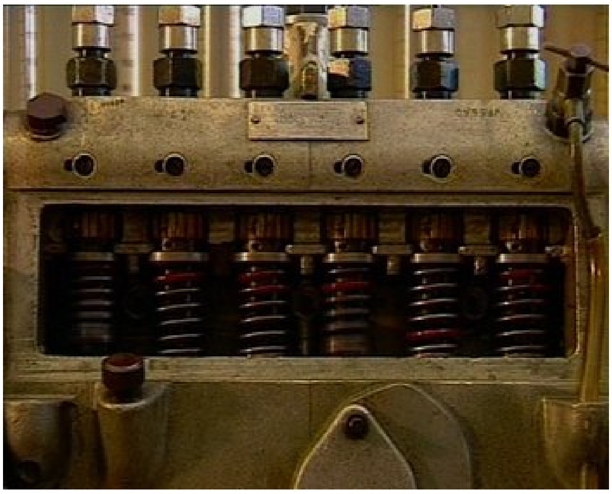
Diesel engines need assistance to make cold starting easier. Most diesel fuel injection systems inject extra fuel when starting, to ensure sufficient fuel will vaporize and burn in the combustion chamber. Indirect injection engines may also use heater plugs, or glow plugs, which usually screw directly into the combustion chamber. They only heat the air, and do not begin the combustion.

## 7.2 Inline Injection Pump

Some diesel engines use in-line injection pumps to meter, and raise the pressure of the fuel. The basic principle is for a plunger to act on a column of fuel, to lift an injector needle off its seat.

Inside the pump are a pumping element, and a delivery valve for each cylinder of the engine. The element has a barrel, and a plunger that fits inside it. Their accurate fit and highly-polished finish ensures only minimal fuel leakage past them, without needing positive seals. The barrel usually has 2 holes, or ports, called the inlet port, and the spill port. They connect the inside of the barrel with the gallery. The gallery contains filtered fuel from the low-pressure system. At the top of the barrel are a delivery valve, delivery valve holder, and the pipe to carry fuel to each cylinder.

The upper end of the plunger has a vertical groove, extending from its top to an annular groove. The top edge of this annular groove is cut in a helix, also called the control edge. Some pumps have a helix cut on top of the plunger.



A camshaft, cam follower and spring, move the plunger in a reciprocating motion.

When the plunger is below the ports, fuel from the gallery enters the barrel above the plunger. This ensures the barrel is full of fuel. As the camshaft rotates, the plunger is pushed past the ports. The highly polished surfaces cause a sealing effect, trapping the fuel above the plunger. Moving the plunger further raises the pressure of the fuel. This forces the fuel out past the delivery valve, along the fuel line to the injector.

Fuel flows to the injector until the control edge uncovers the spill port. The pressurized fuel above the plunger then moves down the vertical groove, to the annular groove, and into the spill port. The delivery valve stops fuel leaking from the pipe back into the element. It reduces pressure in the fuel line to ensure there is no dribbling by the injector.

The delivery valve has a relief plunger, and a conical face which is held against its matching seat by the delivery valve spring. The relief plunger on the valve is a close fit inside the bore of the delivery valve seat.

When the fuel pressure rises, the delivery valve is lifted off its seat. When the plunger is clear of its bore, fuel flows to the injector. When injection ceases, the pressure below the delivery valve drops to gallery pressure.

Fuel pressure above the delivery valve forces the valve towards its seat. The relief valve enters the seat bore, sealing the volumes above and below the delivery valve. Further movement of the delivery valve towards its seat, increases the volume in the injector pipe, and reduces the pressure in there. This drop in pressure causes the injector needle to snap shut, helping to prevent fuel dribble from the injector. The conical face of the delivery valve then contacts the seat, further sealing the plunger from the injector pipe.

Rotating the plunger controls the length of the stroke for which the spill port is covered. This is called the effective stroke. It influences how much fuel is delivered to the injector. A short effective stroke means a small amount of fuel is injected. A longer effective stroke lets more fuel be delivered. To stop the engine, the vertical groove on the plunger is aligned with the spill port, which stops pressure in the barrel rising.

The plunger is rotated by a control sleeve, a rack, and a pinion. Moving the rack rotates the pinion, the control sleeve, and then the plunger. The rack's movement is controlled by the governor.

## 7.3 Distributor Type Injection Pump

The distributor-type pump uses a vane-type transfer pump to fill the single pumping element. This then raises fuel pressure to injection pressure. A distribution system then distributes fuel to each cylinder, in the firing order of the engine. The most common type in light automotive use is the Bosch VE pump. A drive shaft driven from the engine rotates a plunger, and a cam disc. Cams on the face of the disc have as many lobes as cylinders in the engine. A plunger spring holds the cam disc against rollers that rotate on their shafts.

The lobes move the plunger to-and-fro in its barrel, making it rotate, and reciprocate, at the same time. Its rotation operates the fuel inlet port to the pumping chamber, and at the same time distributes pressurized fuel to the correct injector. The reciprocating motion pressurizes the fuel in the pumping chamber.

The plunger's pumping action forces fuel through a delivery valve, to the injector. This pump is for a 3-cylinder engine, so it has 3 delivery valves. The barrel has 1 intake port and 3 distribution ports. The plunger has a central passage, a connecting passage to the distributing slit, and a cross-drilling to a control sleeve. As the plunger rotates, each intake slit aligns with the intake port, and the distributing slit with the distributing port. As the plunger rotates, the intake slit moves away from the intake port. At the same time, the plunger is acted on by the cams, causing it to move axially along the barrel, pressurizing the fuel in the pumping chamber. The distributing slit now uncovers the distribution port, and the pressurized fuel passes through delivery valve to the injector.

Further rotation of the plunger closes off the distribution port, and opens the intake port. At the same time, the plunger spring moves the plunger back along the barrel for the next pumping stroke.

For intake, fuel from the feed pump reaches the open intake port in the barrel. The intake slit aligns with the intake port, and fuel fills the pumping chamber and passages in the plunger.

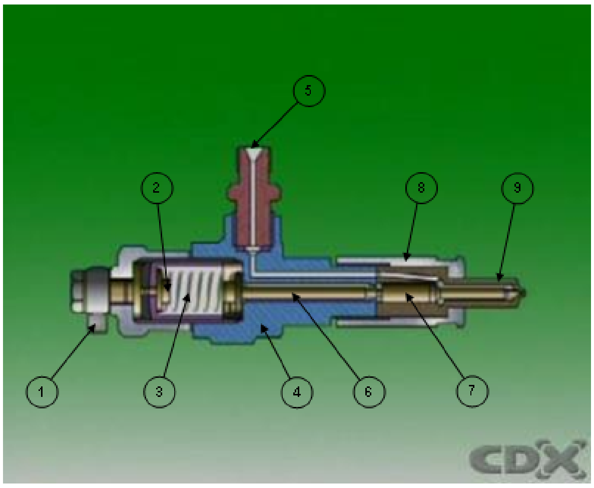
For injection, the plunger rotates to close off the intake port, and moves along the barrel, to pressurize fuel in the pumping chamber. The distributing slit aligns with the distribution port and the pressurized fuel forces the delivery valve off its seat, and reaches the injector. In this phase, a cut-off port in the plunger is covered by the control sleeve. To end fuel delivery, the plunger's cut-off port moves out of the control sleeve, and lets pressurized fuel spill back into the pump housing. This relieves pressure in the pumping chamber, the delivery valve closes, and injection ceases.

Metering the fuel is controlled by effective stroke of the control sleeve, and that's determined by the action of the governor sliding the control sleeve along the plunger. Sliding it one way opens the cut-off port earlier, and reduces effective stroke. Sliding it this way delays its opening, and increases effective stroke. The governor changes the position of the control sleeve to vary the quantity of fuel delivered, according to throttle position and load. When the ignition is switched off, an electrical solenoid closes off the intake port, and stops fuel delivery.

# 7.4 Diesel Injectors

Most diesel fuel injectors use the same basic design, made from heat-treated alloy steel. The actual shape will vary according to the application.

The injector assembly has several main parts. The nozzle assembly is made up of a needle and body. A pressure spring and spindle hold the needle on the seat in the nozzle body. A nozzle holder, sometimes called the injector body, may allow for mounting the injector on the engine, and some method of adjusting the spring force applied to the needle valve. A cover keeps out dirt and water.




**Components identified**

1. “Fuel return to tank” (leak off)
2. Pressure adjusting shim
3. Pressure spring
4. Injector body
5. High pressure fuel supply
6. Pressure pin
7. Needle valve
8. Nozzle retaining nut
9. Nozzle

The injection pump delivers fuel to the injector. The fuel passes through a drilling in the nozzle body, to a chamber above where the needle-valve seats in the nozzle assembly. As fuel pressure in the injector gallery rises, it acts on the tapered shoulder of the needle valve, increasing the pressure until it overcomes the force from the spring, and lifts the needle valve from its seat. The highly pressurized fuel enters the engine at a high velocity, in an atomized spray.

As soon as delivery from the pump stops, pressure under the needle tapered-shoulder drops, and the spring force pushes the needle down on the seat, cutting off the fuel supply to the engine.

## Leak off pipes

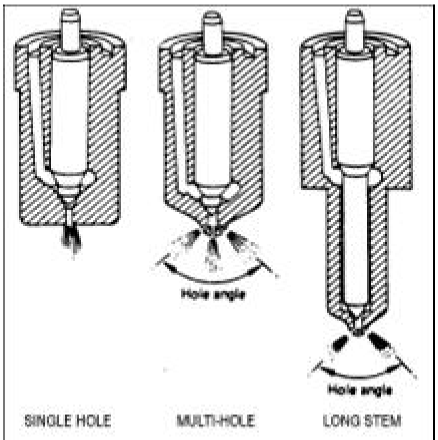
Some of the fuel is allowed to leak between the nozzle needle and the body, to cool and lubricate the injector. This fuel is collected by the leak- off line, and returned to the fuel tank for later use.

## Injector nozzle

The two main types of nozzle in service are the hole types and the pintle types.

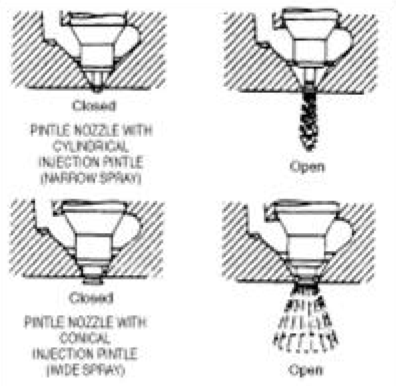
## Hole Types

These are used in conjunction with direct injection combustion chamber. They may be of normal or long-stem type. The latter being used where either space is restricted or heat may be excessive. The four hole injector is the most common arrangement as it provides a symmetrical pattern of spray. The size and length of the hole determines the shape and penetration of the atomized spray.

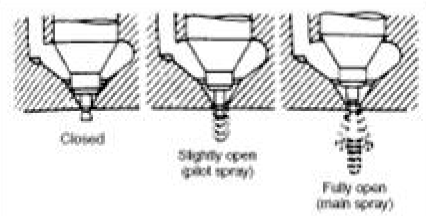


Hole type nozzles.

**Pintel nozzle:** These are used in conjunction with the indirect injection combustion chamber which always have adequate air turbulence. They spray at a much lower pressure than the holed type and in some types the lower part of the needle is of special shape so that a slight movement of the needle results in the delivery of a preliminary spray. The main delivery being slightly delayed. This results in a more gradual pressure rise in the combustion chamber and a smoother running engine.

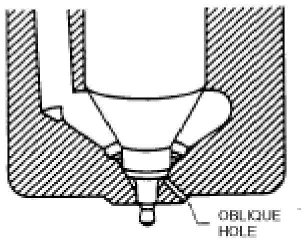


*Pintel type nozzles.*



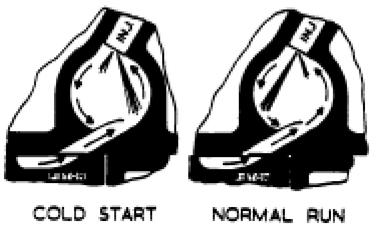
*Delay nozzle.*

**Pintaux nozzle:** A further development of the pintle nozzle is the pintaux nozzle design. It is designed to aid starting of the indirect injection type engine by using a nozzle with an oblique hole to direct fuel to the hottest part of the antechamber "B" (heat plug side) under the starter cranking speed.



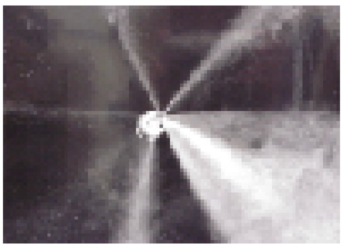
*Pintrux fuel injection nozzle.*

When the engine starts the spray is now directed out of the main spray hole to the hottest part of the antechamber “A” when the engine is running.

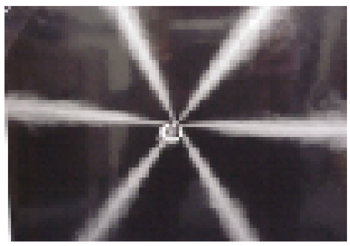




In **pintle-type nozzles**, a pin, or pintle, protrudes through a spray hole. The shape of the pintle determines the shape of the spray, and the atomization of the spray pattern. Pintle nozzles open at lower pressures than hole-type nozzles. They are used in indirect injection engines, where the fuel has a comparatively short distance to travel and the air is not as compressed as in the main chamber.

**Picture shows spray pattern images of “hole” type injector that help diagnose injector condition**

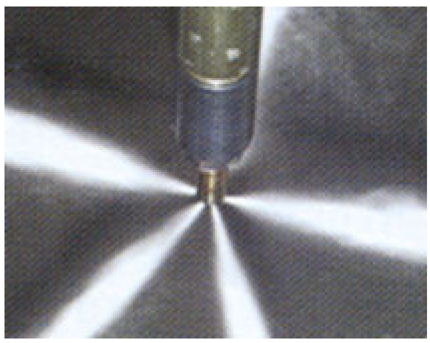


**Distorted spray pattern**



**Optimum spray pattern**

**Poor spray pattern with clogged injector.**



**Uniform spray pattern with clean injector.**

## 7.5 Diesel Injector Testing

Diesel injector testing can only be carried out using manufactures recommend procedures.

### Injector inspection

A faulty injector may be diagnosed by:

1. Excessive smoke emission from engine exhaust.
2. Engine misfiring.
3. Diesel knock.
4. Loss of power.

To locate the faulty injector, slacken off the injector pipe union of each injector in turn (similar to shorting out spark plugs on a petrol engine). The faulty injector is the one which produces no change in the running of the engine when the pipe union is slackened. Once located the injector may be removed and tested on a test rig. It is advisable to check the condition of the injectors for serviceability at regular intervals to ensure good engine performance.

**STEP 1:** Ensure injector is fitted in testing rig correctly as the spray from the injector can easily penetrate the skin.

**STEP 2:** Breaking Pressure

This test checks the injector for incorrect spring tension broken spring, or sticking needle valve. Operate machine and note breaking pressure of injector, compare with manufacturers specification. Adjust if necessary.

**STEP 3:** Spray Formation

This test checks the injector for holes partly blocked, carbon at needle valve tip, pintle damaged. Operate machine rapidly and check spray formation:

a) Multi-hole nozzle should all travel through the same distance and have a similar form, appearing as a fine mist without distortion and without visible streaks of unvaporized fuel. Buzzing sound should be heard. Delay type injectors may not buzz on test rig.
b) Pintle nozzles with the preliminary spray under engine cranking speed. Operate machine slowly and check formation of preliminary spray and then rapidly to check main spray, both should spray without distortion.

**STEP 4:** Nozzle seat dryness This checks the injector for needle valve sticking incorrect seating or carbon deposits. Clean and dry nozzle tip. Operate machine until injector pressure is 10 BARS below breaking pressure and hold for 20 - 40 seconds. Release handle hold bloting paper against nozzle tip and check size of stain it should not exceed 12mm in diameter, leakage dribble causes carbon deposits at nozzle tip or pintle.

- Never Hold Blotting Paper Against Nozzle Tip when The Machine Lever is Being Pressed.

**STEP 5:** Back leakage This test checks the condition of the injectors needle valve and body for wear. Operate machine until 10 BARS below breaking e pressure. Isolate pump, release hand lever and allow pressure to fall off naturally. Record the time it takes for the pressure to drop:

(a) 50 BARS for holed type in 6-30 seconds.
(b) 25 BARS for pintle in 6-30 seconds.

A drop of pressure below 6 seconds, needle valve and nozzle worn, shoud be replaced. A drop of pressure in excess of 30 seconds, needle valve too tight in nozzle, may cause sticking. Check for visible leaks at nozzle to injector body joint etc. Which would cause excessive drop in pressure. Remove, clean and reassemble joint and torque to correct pressure.

| **Fault** | **Cause** |
|---|---|
| Nozzle does not buzz | Valve binding or seal leakage cap nut distorted |
| Leak off excessive | Worn needle and nozzle. Dirt between face of nozzle and holder. Slack nozzle cap |
| Injector pressure too high | Spring tension too tight. Valve seized. Block nozzle holes |
| Injector pressure too low | Spring tension too low. Spring broken. Needle valve stuck open |
| Nozzle seat drip | Valve sticking. Worn needle valve to nozzle seat |
| Distorted spray | Holes partly blocked. Pintle damaged. |

# 8.0 Cold Starting Devices

## *8.1 Glow Plugs*

**Glow plugs** are used to heat the combustion chambers of diesel engines in cold conditions to help ignition at cold start. In the tip of the glow plug is a coil of a resistive wire or a filament which heats up when electricity is connected.

Glow plugs are required because diesel engines produce the heat needed to ignite their fuel by the compression of air in the cylinder and combustion chamber. Petrol engines use an electric spark plug. In cold weather, and when the engine block, engine oil and cooling water are cold, the heat generated during the first revolutions of the engine is conducted away by the cold surroundings, preventing ignition. The glow plugs are switched on prior to turning over the engine to provide heat to the combustion chamber, and remain on as the engine is turned over to ignite the first charges of fuel. Once the engine is running, the glow plugs are no longer needed.

Indirect-injection diesel engines are less thermally efficient due to the greater surface area of their combustion chambers and so suffer more from cold-start problems. They require longer pre-heating times than direct-injection engines, which often do not need glow plugs at all in temperate or hot climates even for a cold start.

In a typical diesel engine, the glow plugs are switched on for between 10 and 20 seconds prior to starting. Older, less efficient or worn engines may need as much as a minute (60 seconds) of pre-heating.

Large diesel engines as used in heavy construction equipment, ships and locomotives do not need glow plugs. Their cylinders are large enough so that the air in the middle of the cylinder is not in contact with the cold walls of the cylinder, and retains enough heat to allow ignition.

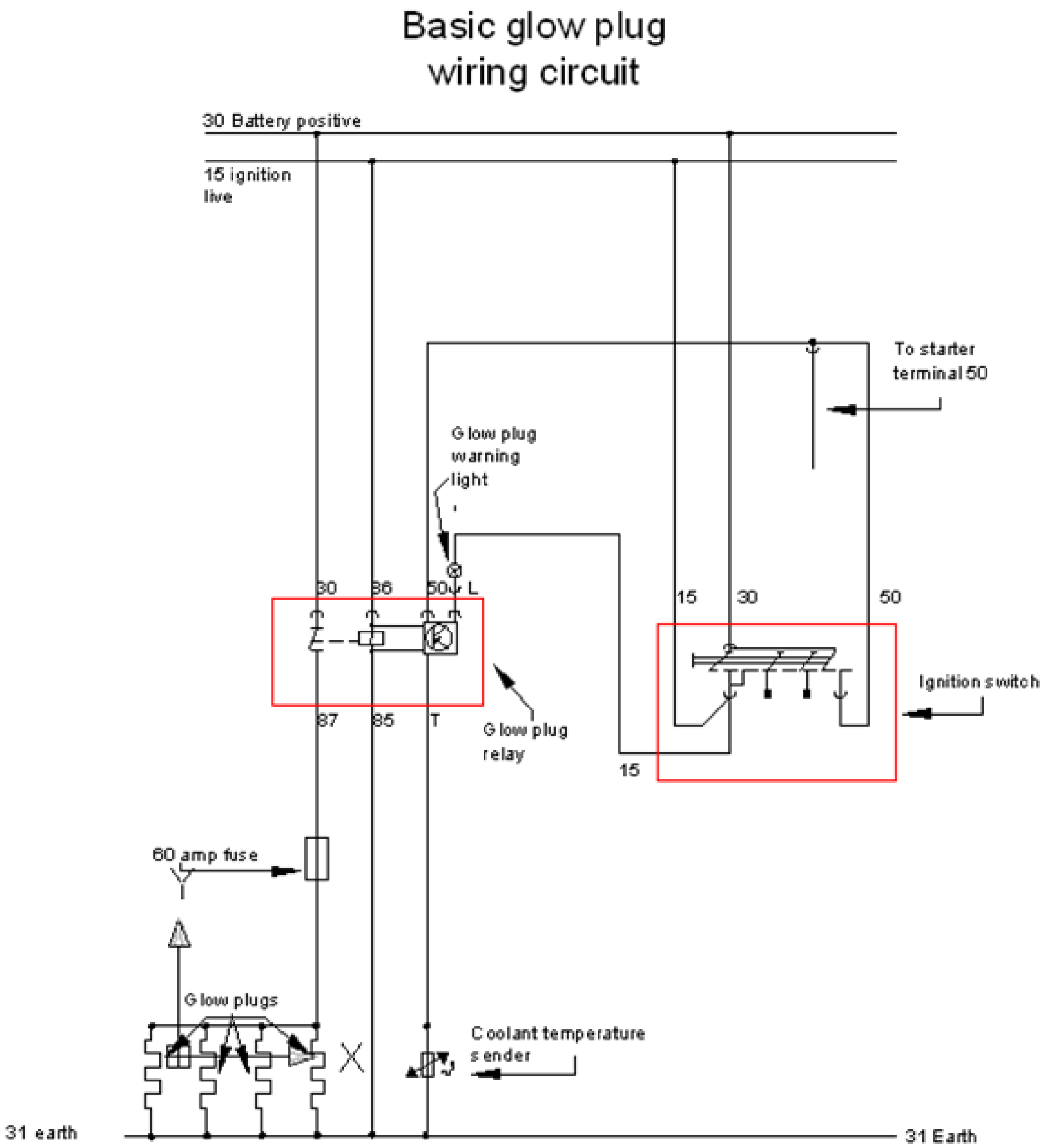
Modern automotive diesel engines with electronic injection systems use various methods of altering the timing and style of the injection process to ensure reliable cold-starting. Glow plugs are fitted, but are rarely used for more than a few seconds.

Glow plug filaments must be made of materials such as platinum and iridium that are resistant both to heat and to oxidation and reduction by the burning mixture. These particular materials also have the advantage of catalytic activity, due to the relative ease with which molecules adsorbed on their surfaces can react with each other. This aids or even replaces electrical heating.

## 8.2 Glow Plug Circuit

### Cold Starting

Cold starting compression-ignition engines can be a problem because of initial heat losses. This is particularly so with indirect injection type. The difficulty can be overcome in several ways. At the cylinder head end these plugs have either a small tube or a coil of wire which glows at red heat when switched on. Modern heater plug systems are energised from 7 to 17 seconds depending on type. The plugs are energised just before cranking for the prescribed time period to give a tip temperature of about 1000C.




**The above system consists of a time-controlled relay, coolant temperature sender, glow-plug warning light, 60 amp fuse, glow plugs, ignition switch and related wiring. More information can be sourced from automotive technical manuals. The power rating of approximately 75 Watts is required by each plug.**

# 8.3 Basic Testing For A Glow Plug /Circuit

Test procedure is as follows:

*(Reproduced courtesy of Autodata Ltd, Unit 5 Priors Way, Maidenhead, England)*

| | | | |
|---|---|---|---|
| **Manufacturer:** | Volkswagen | **Model:** | Golf (98-06) 1,9D TDI |
| **Engine code:** | AGR | **Output:** | 66 (90) 4000 |
| **Tuned for:** | Year: 1997-02 | | © Autodata Limited 2006 |

## Glow plugs

### Checking resistance - Fig. 4

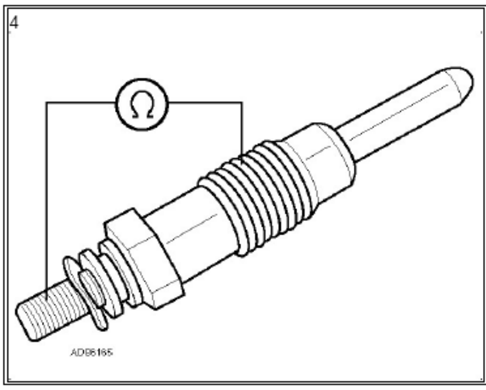
| Technical Data | |
|---|---|
| Resistance | 0,4 Ω approx. |

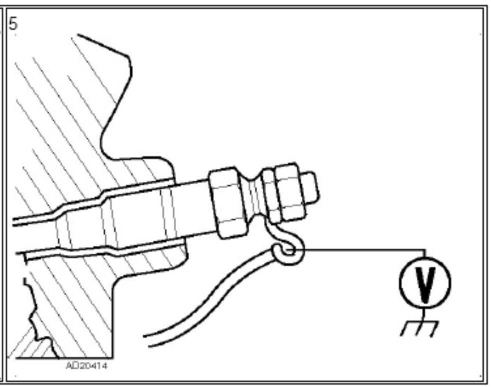
- Ensure ignition switched OFF.
- Remove glow plug.
- Check resistance between terminal and body.

### Checking pre-heating - Fig. 5

| Technical Data | |
|---|---|
| Glow period | 15-20 seconds |

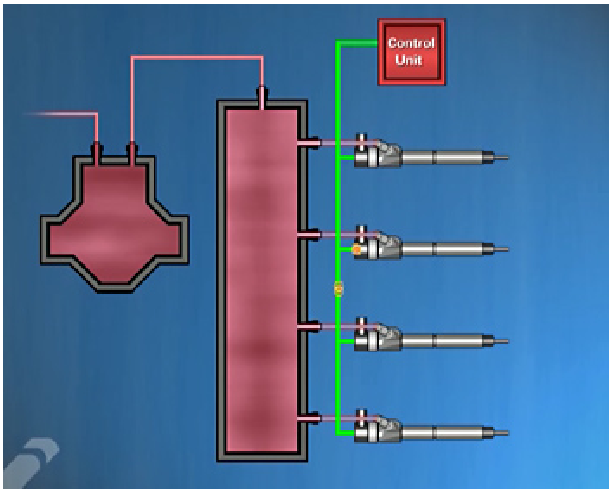
- Ensure ignition switched OFF.
- Disconnect engine coolant temperature (ECT) sensor multi-plug.
- Access glow plug terminal. Connect voltmeter between glow plug terminal and earth.
- Switch ignition ON.
- Check glow period.



# 9.0 Diesel Electronic Control Systems

Diesel engines are subject to very high stresses during compression and ignition, and increasingly stringent emission standards have made better control of the diesel combustion process necessary.




Electronic controlled diesel systems give very precise control of the fuel injection and combustion process. Electronic controls have delivered other benefits besides a reduction in fuel consumption and emissions, such as an increase in power and torque; improved engine responsiveness; a reduction in engine noise and diesel knock; and improved and expanded diagnostic capabilities through the use of scan tools.

Diesel electronic control systems monitor and control many variables, including:

1. Engine speed:

   - to maintain a smooth functional idle,
   - and to limit the maximum safe engine speed, power, and torque;
   - and to keep the engine output to within safe limits.

2. Fuel injector operation:

   - including the timing, rate and volume of fuel injected.

3. Glow plugs and heater elements:

    - Control of pre-heating of the intake air to support quick cold starting and reduced cold run emissions.

4. Exhaust emissions:

    - Analysis of exhaust gas to determine combustion efficiency and pollutants.

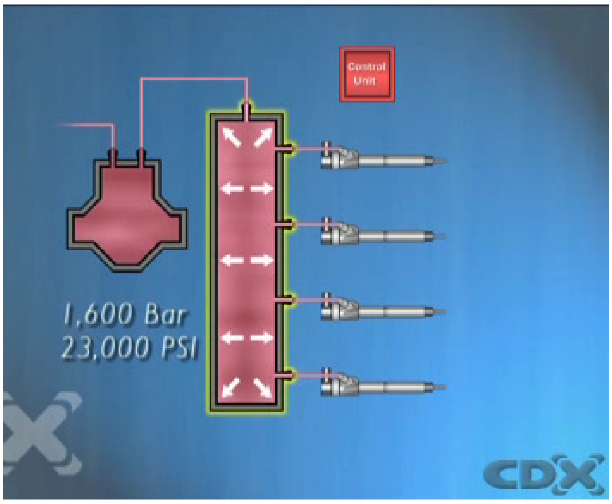
5. And the data bus:

    - An electronic communications network that allows exchange of data between computers - necessary for efficient operation and fault diagnosis.
    - Other inputs monitored include:
    - Crankshaft position,
    - Throttle position,
    - Brake and clutch operation,
    - Battery voltage,
    - Cruise control request,
    - Air, oil fuel, exhaust and coolant temperatures,
    - Intake air, oil and fuel pressures.

## 9.1 Common Rail Diesel Injection System

The Common Rail Diesel Injection System delivers a more controlled quantity of atomised fuel, which leads to better fuel economy; a reduction in exhaust emissions; and a significant decrease in engine noise during operation.

In the Common Rail system, an accumulator, or rail, is used to create a common reservoir of fuel under a consistent controlled pressure that is separate from the fuel injection points. A high-pressure pump increases the fuel pressure in the accumulator up to 1,600 bar or 23,200 PSI. The pressure is set by the engine control unit and is independent of the engine speed and quantity of fuel being injected into any of the cylinders. The fuel is then transferred through rigid pipes to the fuel injectors, which inject the correct amount of fuel into the combustion chambers.




The injectors used in Common Rail systems are triggered externally by an Electronic Diesel Control, or EDC unit, which controls all the engine injection parameters including the pressure in the fuel rail and the timing and duration of injection.

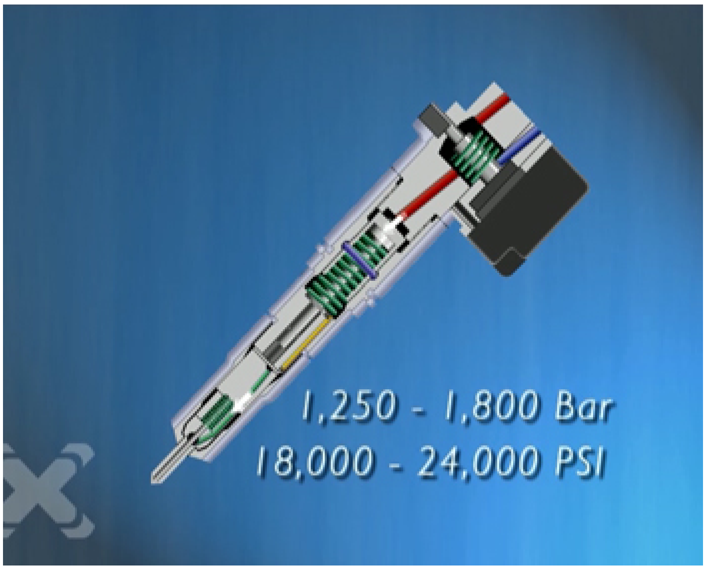
Diesel fuel injectors used in Common Rail injection systems operate differently to conventional fuel injectors used in the jerk pump system, where the plungers are controlled by the camshaft position and speed. Some common rail injectors are controlled by a magnetic solenoid on the injector. Hydraulic force from the pressure in the system is used to open and close the injector, but the available pressure is controlled by the solenoid triggered by the Electronic Diesel Control unit.

Some injectors use Piezo crystal wafers to actuate the injectors. These crystals expand rapidly when connected to an electric field. In a Piezo inline injector, the actuator is built into the injector body very close to the jet needle and uses no mechanical parts to switch injector needles.

The electronic diesel control unit precisely meters the amount of fuel injected, and improves atomization of the fuel by controlling the injector pulsations. This results in quieter, more fuel efficient engines; cleaner operation; and more power output.

## 9.2 HEUI Diesel Injection System

The Hydraulically actuated, electronically controlled Unit Injector or HEUI system of diesel fuel injection operates by drawing fuel from the tank using a tandem high and low pressure fuel pump. The pump circulates fuel via the 'low' side of the pump at low pressure through a combination of fuel filter, water separator, and heater bowl, and then back through the 'high' side of the pump at high pressure into the fuel galleries located in the cylinder head, and through to the injector units.




The injectors are controlled by a Power train Control Module or PCM. Although the PCM controls the duration of fuel injection pulses based on a range of inputs, oil from a high-pressure oil pump hydraulically actuates the injectors.

By varying the oil pressure, injection can be controlled independently of the position or speed of the engine crankshaft or camshaft. A solenoid-actuated valve controls the high-pressure oil flow which is applied to the top of an intensifier piston in the injector. This can increase injection pressures to 1250 to 1800 Bar or 18,000 to 24,000 PSI.

The area of the head of the intensifier piston is approximately 7 times the area of its plunger. As a result a 7:1 pressure increase on the fuel beneath the plunger can be achieved.

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