Phase 2

Trade of Motor Mechanic

Module 9

Unit 1

C.I Principles & Diesel Fuel System

Produced by

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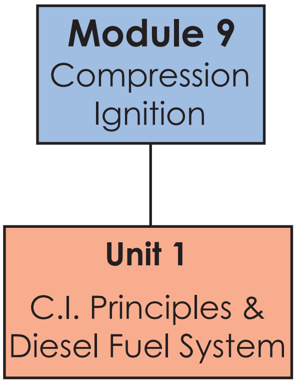
Table of Contents

Introduction

Module 9 of this course covers the compression ignition engine aspect of automotive technology. There is only one unit in this module it covers the fundamental principles and components associated with the compression ignition engine. By the end of this unit you will be able to understand its application in automotive technology and the operation of the components that are used in the compression ignition engine.



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. In a basic diesel fuel system a fuel tank holds the diesel fuel. A lift pump takes fuel from the tank this keeps the injection pump full of fuel. A sedimenter removes any water and larger particles in the fuel. A fuel filter removes minute particles. 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. An injector at each cylinder sprays fuel into each combustion chamber. Leak-off pipes take fuel used for cooling and for lubrication from the injection pump and injectors back to the tank. This unit will cover the key components associated with the compression ignition engine and the relevant environment, health and safety.

Unit Objective

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

- State and apply the safety and precautionary procedures applicable to working on the Compression Ignition (C.I.) engine and diesel fuel injection system
- Identify the correct fire extinguisher required for diesel fuel fires
- Describe the properties of diesel fuel
- State the fundamental principles of operation of the C.I. engine
- Distinguish between C.I. combustion chamber designs
- Outline the main features of the C.I. combustion process
- Illustrate the component configuration of an automotive diesel fuel injection system
- State the purpose of the components associated with the diesel fuel injection system
- Identify the purpose and methods of air and fuel filtration used for an automotive diesel system
- Remove and replace a diesel fuel filter and bleed the system
- Describe the structure and principles of operation of the diesel fuel injector
- Dismantle a diesel fuel injector, identify the components and reassemble
- Check the spray pattern of a diesel fuel injector and report on its condition
- State the functions of a glow plug in a C.I. engine
- Draw a simple glow plug circuit and describe its operation
- Test the operation of the glow plug circuit and plugs
- State the safety issues and precautions associated with working on Common Rail diesel fuel injection and PD (Pumpe Düse) pump unit injection systems
- Check the idle speed on a C.I. engine
- State the NCT/DoT VTM requirements applicable to the diesel fuel system and compression ignition engine emissions
- Check the exhaust emissions from a compression ignition engine

1.0 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 Düse) 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).

2.0 Precautions and Safety Issues

Safety issues and precautions associated with working on Common Rail diesel fuel injection and PD (Pumpe Düse) pump unit injection systems.

- Awareness of high fuel system pressures e.g. up to approx. 2000 Bar
- Recognition of compulsory requirement for fuel system pressure release/discharge prior to disconnection of fuel lines to avoid personal injury danger of high voltage at injector solenoids
- Use of non-powdered latex gloves and lint free cloths
- Use of eye protection appropriate cleaning procedure prior to component removal
- Use of blanking plugs on open lines to avoid foreign matter ingress
- Importance of cleanliness
- Awareness that the electrical block connection from the injector must never be disconnected when the engine is running and above all the need for investigation and consideration of manufacturer's recommended safety and precautionary procedures prior to and during all common rail/PD fuel system repair operations

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

3.0 Fire Extinguisher Required for Diesel Fuel Fires

Key Learning Points

- Identification of the correct fire extinguisher required for diesel fuel Fires

3.1 Diesel Fire Classification

"B" class fires involve flammable liquids such as diesel.

Carbon dioxide fire extinguishers are most effective when used against "B" "C" and "E" class fires. The gas is heavier than air and provides an inert blanket that smothers the fire. A carbon dioxide fire extinguisher will spray small ice particles with the gas. This is normal.

Dry Powder fire extinguishers contain a fine powder usually sodium bicarbonate held under pressure by an inert gas. The extinguisher smothers the fire with a fine powder. These extinguishers are good to fight any fuel or liquid fire.

Foam fire extinguishers contain a chemical that forms a soft foam that floats over the target area and smothers the fire.

4.0 Properties of Diesel Fuel

Key Learning Points

- Properties of diesel fuel (including cetane rating self-ignition temperature viscosity sulphur content cooling and lubrication purposes corrosive effect of water-contaminated diesel low temperature wax formation etc.)

4.1 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 sound is 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.

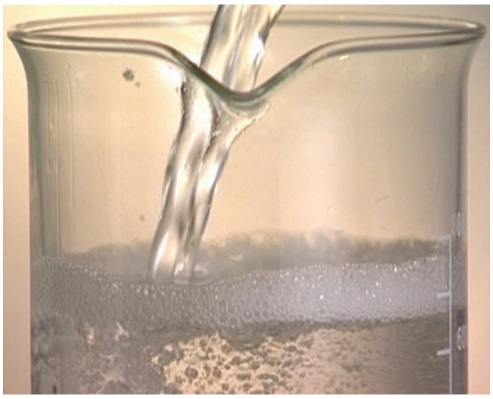
4.2 Diesel Fuel Properties

Properties of Diesel Fuel: The following qualities are present in 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.

5.0 Principles of Operation of the C.I. Engine

Key Learning Points

- Fundamental principles of operation of the C.I. engine (including C.I. four-stroke cycle air-only induction fuel-only controlled by driver structural differences between C.I. and SI engine comparison with spark ignition four stroke cycle etc.)

5.1 Basic Four-Stroke Diesel Principles

A diesel engine 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.

Then Ignition burns the mixture. It is just the heat of the compressed air that ignites the fuel. That's why diesels are called compression ignition engines (C.I.).

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.

5.2 Four-Stroke Diesel Engine Cycle

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 a fuel tank holds the diesel fuel. A lift pump takes fuel from the tank. It keeps the injection pump full of fuel. A sedimenter removes any water and larger particles in the fuel. A fuel filter removes minute particles. 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. An injector at each cylinder sprays fuel into each combustion chamber. 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. A governor controls engine speed. And a control lever on the governor is connected to the accelerator pedal.

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-nineteenth 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 and above 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.

6.0 C.I. Combustion Chamber Designs

Key Learning Points

- C.I. combustion chamber designs (including location of combustion chamber in direct and indirect injection pre-combustion/swirl antechamber; comparison of direct/indirect injection with reference to turbulence compression ratios heat loss etc.)

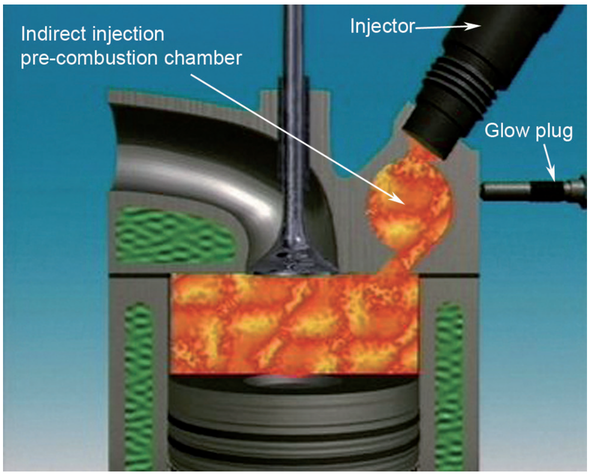
6.1 Diesel Fuel Delivery

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. The engine in comparison to indirect injection has a higher compression ratio which generates more heat.

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.

6.2 Diesel Combustion Chambers



Diesel combustion chambers between Direct and indirect injection are different. 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 pre-combustion/swirl antechamber 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.

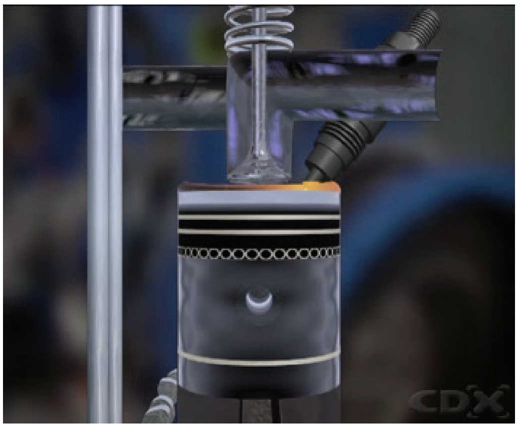
When injection commences combustion pressure forces the air to flow from the air cell where it mixes with fuel from the injector. The rush of air from the air cell produces a rotary motion of gas in the main chamber which helps make combustion more efficient. The pre-combustion chamber is screwed into 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.

6.3 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.



This is a picture of a direct injection engine cylinder.

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.

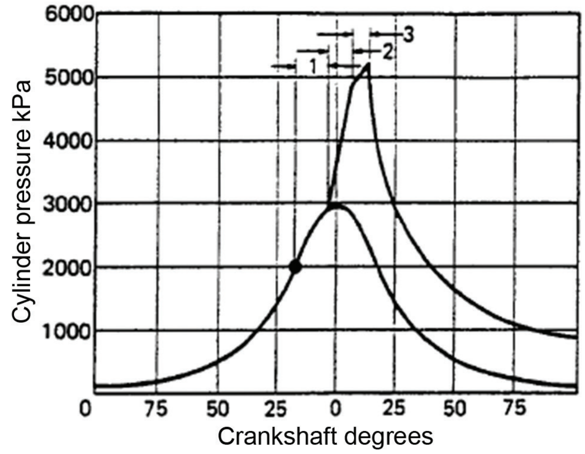
7.0 Main Features of the C.I. Combustion Process

Key Learning Points

- Main features of C.I. combustion process (including turbulence air temperature timing of injection ignition delay period and the factors that can affect it fuel atomisation diesel knock cylinder pressures emissions etc.)

7.1 Three Phases of Combustion

The combustion process in the cylinder of a C.I. 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

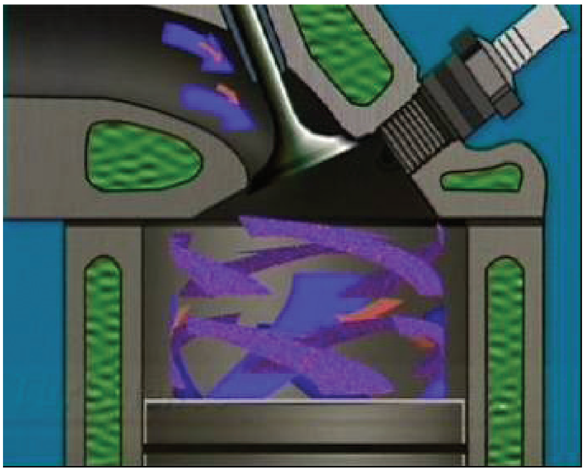
Flame spread causes a sharp pressure rise due to the sudden combustion of the fuel that was injected during the first phase. The rate of pressure rise governs the extent of the combustion knock. This is commonly called 'diesel knock' and is considered to be the main disadvantage of the C.I. engine.

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.

7.2 Turbulence

Turbulence refers to the swirling motion of a liquid or a gas.



It helps to maximise the mixing of air and fuel, which helps make sure the combustion process occurs efficiently. Without turbulence the air-fuel mixture can form local areas of high pressure and temperature that can cause detonation during combustion. A high level of turbulence can prevent this.

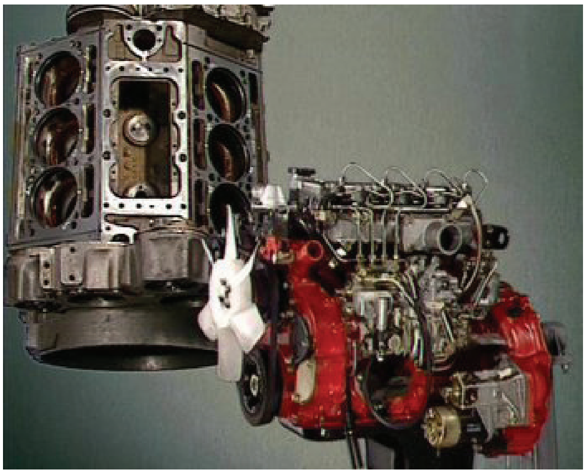
8.0 Diesel Fuel Injection Component Configuration

Key Learning Points

- Component configuration of an automotive diesel fuel injection system

8.1 Diesel Engine Components

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.



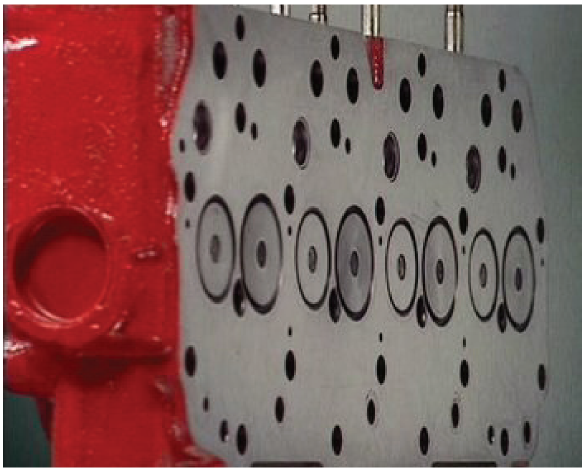
Diesel blocks are usually made of cast iron and heavier than in a petrol engine. The skirt of the block usually extends below the centreline of the crankshaft. This adds strength and rigidity.

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.

8.2 Diesel Engine Passages

4-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.

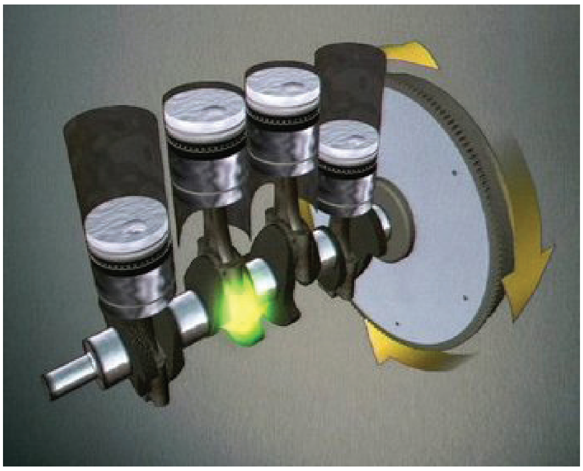
In a petrol engine fuel already mixed with air enters the cylinder and a spark plug ignites it. That's why petrol engines are called spark-ignition engines (SI).

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 (C.I.).

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.

8.3 Diesel Crankshaft

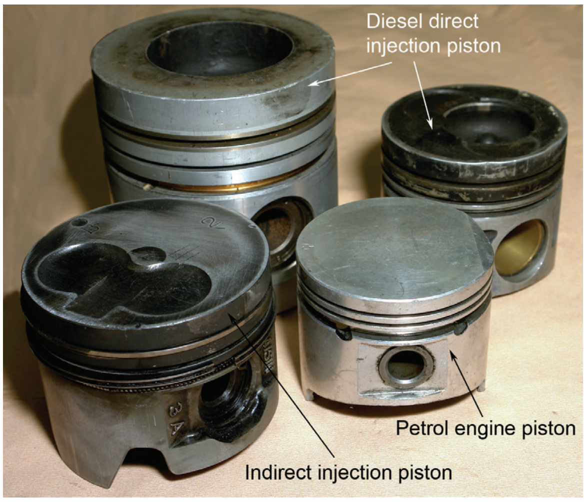
The crankshaft is the same on 4-stroke diesel engines and 2-stroke diesel engines. The shape may appear unusual at first. Crankshaft counterweights keep the rotating components in balance and help the crankshaft turn as smoothly as possible. The crankshaft turns because of the forces transmitted through 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 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 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.

8.4 Diesel Engine Pistons

Pistons in 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.

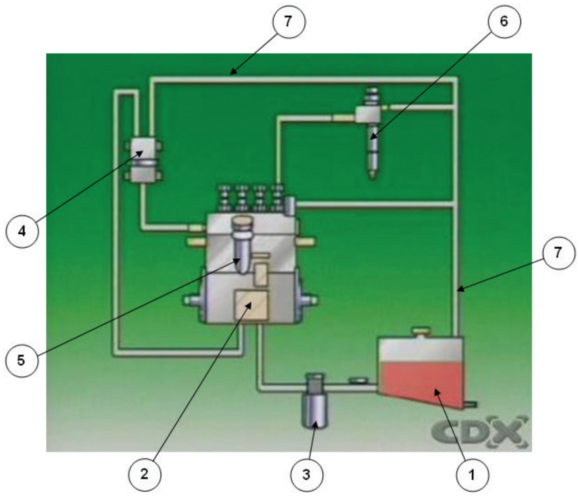
9.0 Diesel Fuel Injection System Components

Key Learning Points

- Purpose of the components associated with the diesel fuel injection system (including the fuel tank lift pump/transfer pump rotary/distributor-type injection pump injector low and high-pressure fuel lines leak-off pipes)

9.1 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.

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.

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.

Note: Section 9.2 to 9.5 covers the low pressure components.

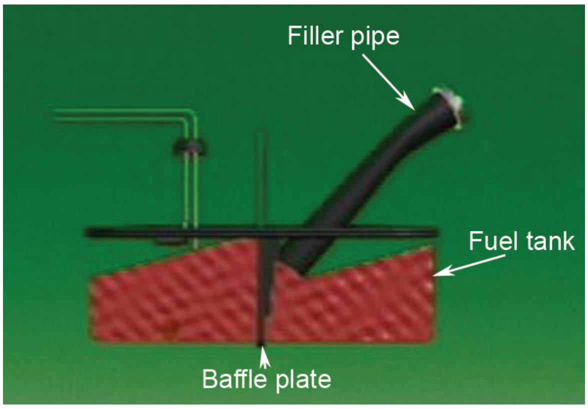
Note: Section 9.6 to 9.10 covers high pressure components.

9.2 Diesel Tanks & Lines

Low Pressure Components

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.

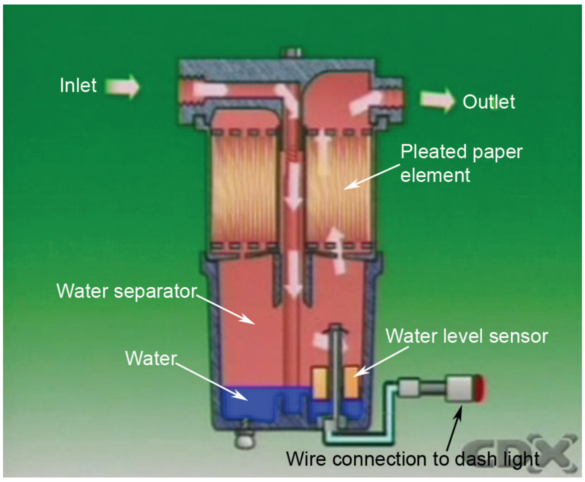
It's supported under the vehicle by nylon insulators in brackets. Reinforced synthetic rubber hoses allow for movement and vibration of components. The reinforcement is needed because the fuel line is subject to variations in pressure.

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.

9.3 Diesel Fuel Filters

Low Pressure Components

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.

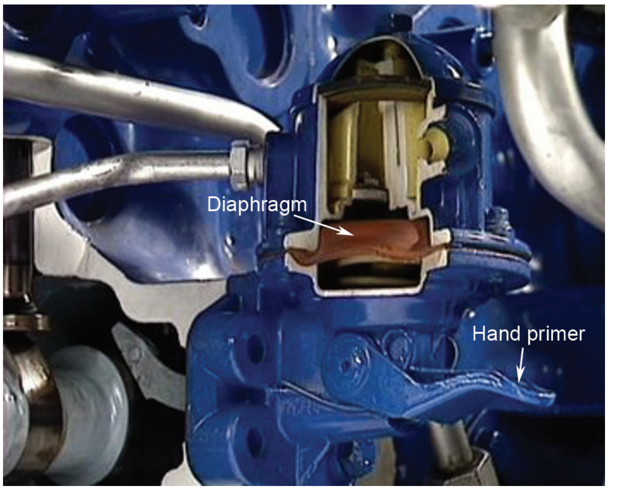
The most common type of filter material in light diesel vehicles is resin-impregnated paper pleated to offer a large surface area to the fuel. These filters are also considered the most efficient. In some of the filters that use this paper fuel flows from outside to inside. In others it flows from the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

9.4 Lift Pump

Low Pressure Components

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.



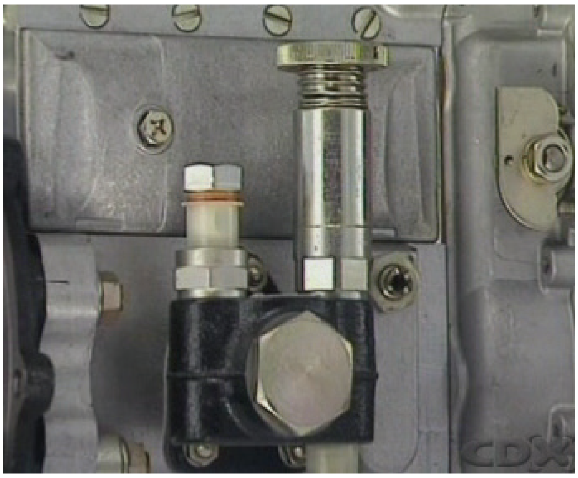
Diaphragm-type pump

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.

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.

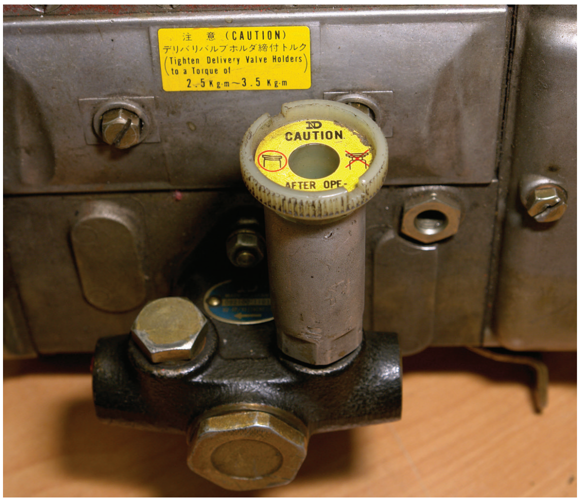
It consists of a rotor mounted off-centre in pump housing. Slots are machined in the rotor to carry vanes. As the rotor rotates the vanes can move into and out of the slots. The vanes seal on the edges of the rotor slots and the pump housing.

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.

9.5 Priming Pump

Low Pressure Components

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.



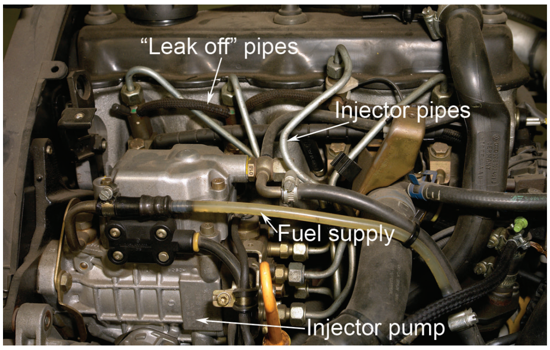
Hand Primer

The 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.

9.6 High Pressure Components

High Pressure Components

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. Pipes that connect these together are known as injector pipes. 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.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.

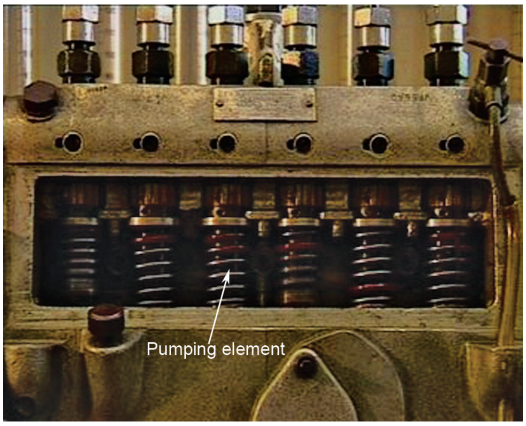
To achieve this control all diesel engines use a governor to control how much fuel is delivered from the injection pump to the injectors and into the engine. There are several types of governors. Some operate mechanically some are pneumatic and some are hydraulic.

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.

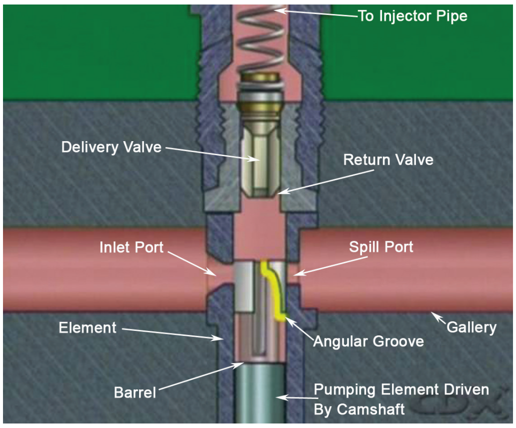
9.7 In-line Injection Pump

High Pressure Components

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 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 raises 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.

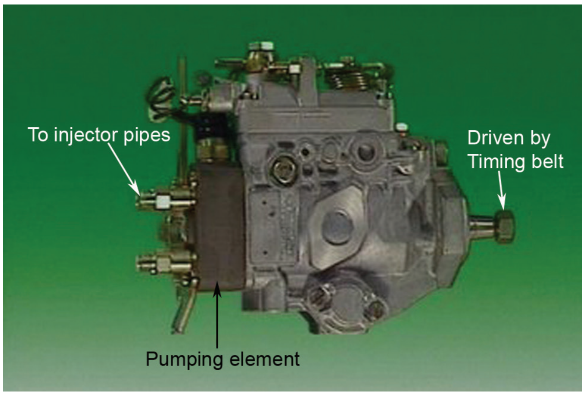
Rotating the plunger controls the length of the stroke for which the spill port is covered and is called the effective stroke. It influences how much fuel is delivered to the injector. A short effective stroke means a small amount of fuel is injected. A longer effective stroke lets more fuel be delivered. 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.

9.8 Distributor Type Injection Pump

High Pressure Components

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.

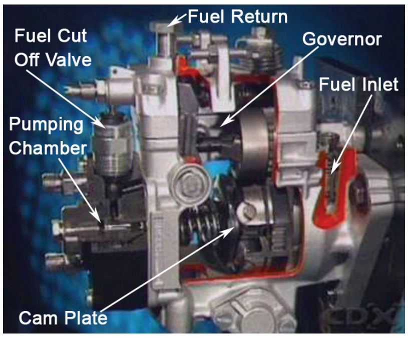


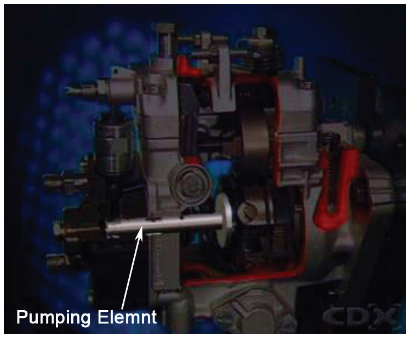
The lobes move the plunger to-and-fro in its barrel making it rotate and reciprocate at the same time. Its rotation operates the fuel inlet port to the pumping chamber and at the same time distributes pressurized fuel to the correct injector. The reciprocating motion pressurizes the fuel in the pumping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

The plunger's pumping action forces fuel through a delivery valve to the injector. A pump for a 3-cylinder engine 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.

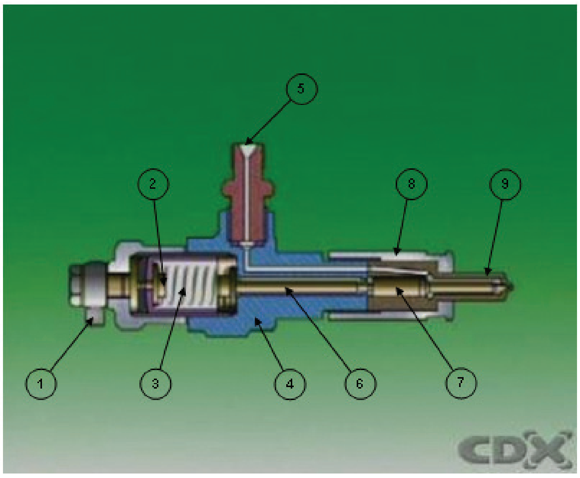
9.9 Diesel Injectors

High pressure components

Most diesel fuel injectors use the same basic design made from heat-treated alloy steel. The actual shape will vary according to the application. Shown here is mechanical type (not electronically operated) injector.

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.

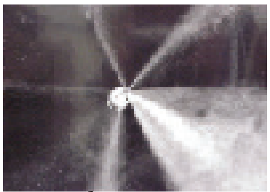
Leak off Pipes

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.

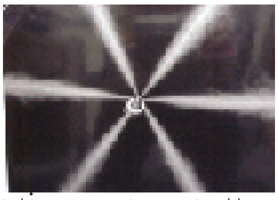
There are 2 main types of injector nozzle hole and pintle.

Hole-type nozzles are commonly used in direct injection engines. They can be single-hole or multi-hole and they operate at very high pressures up to 200 bar. They give a hard spray which is necessary to penetrate the highly compressed air. The fuel has a high velocity and good atomization which is desirable in open combustion chamber engines.

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.

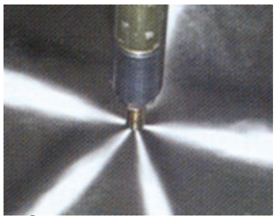


Distorted spray pattern



Optimum spray pattern

Poor spray pattern with clogged injector.



Uniform spray pattern with clean injector.

The pictures shows spray pattern images of "hole" type injector that help diagnose injector condition.

9.10 Diesel Injector Testing

High pressure components

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

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

10.0 Air and Fuel Filtration Used for Automotive Diesel System

Key Learning Points

- Purpose and methods of air and fuel filtration used for an automotive diesel system effects of water and solid-particle contamination draining of water separator

Fuel filter covered in section 9.3

10.1 Air Cleaners

An air cleaner filters air that passes through it to stop harmful particles reaching the engine.

Diesel engines often have more than one air cleaner. This may be due to their severe working conditions. They're usually mounted away from the engine to obtain cleaner cooler air. A lot of air passes through the intake system into the engine. In a petrol engine it's about 15 times the amount of fuel by weight. By volume that's 10,000 times more air than fuel.

The air-fuel mixture enters the engine so the air needs to be clean. Any abrasives that enter the engine can cause wear and damage. It also has a silencing effect, muffling noise produced by the air entering the engine

11.0 Servicing a Diesel Fuel Filter

Key Learning Points

- Use of manufacturer's recommended procedures for removal and replacement of a diesel fuel filter and bleeding the system (primer pump)

The effect of air in fuel system is covered in section 9.6

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

12.0 The Diesel Fuel Injector

Key Learning Points

- Structure and principles of operation of the diesel fuel injector (including hole and pintle type injectors spray patterns injection pressures cooling and lubrication)

Covered in section 9.10

13.0 Servicing a Diesel Fuel Injector

Key Learning Points

- Use of recommended procedures for dismantling/ reassembling diesel fuel injectors
- Identification of diesel fuel injector components

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

14.0 Spray Pattern of a Diesel Fuel Injector

Key Learning Points

- Use of recommended procedures for checking diesel fuel injector (bench unit) spray pattern

Spray patterns are covered in section 9.10

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

15.0 Functions of a Glow Plug in a C.I. Engine

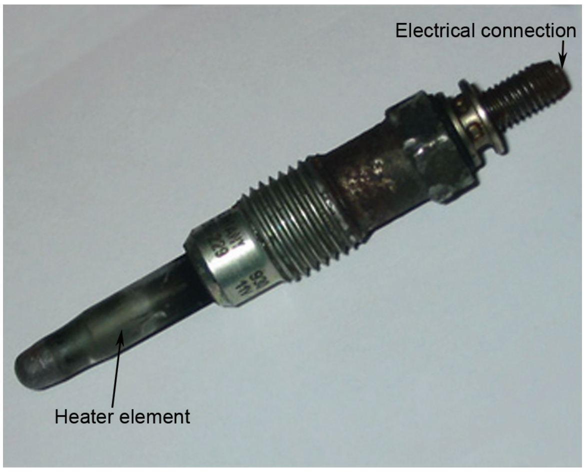
Key Learning Points

- Functions of a glow plug in a C.I. engine

15.1 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 absorbed on their surfaces can react with each other. This aids or even replaces electrical heating.

16.0 The Glow Plug Circuit and its Operation

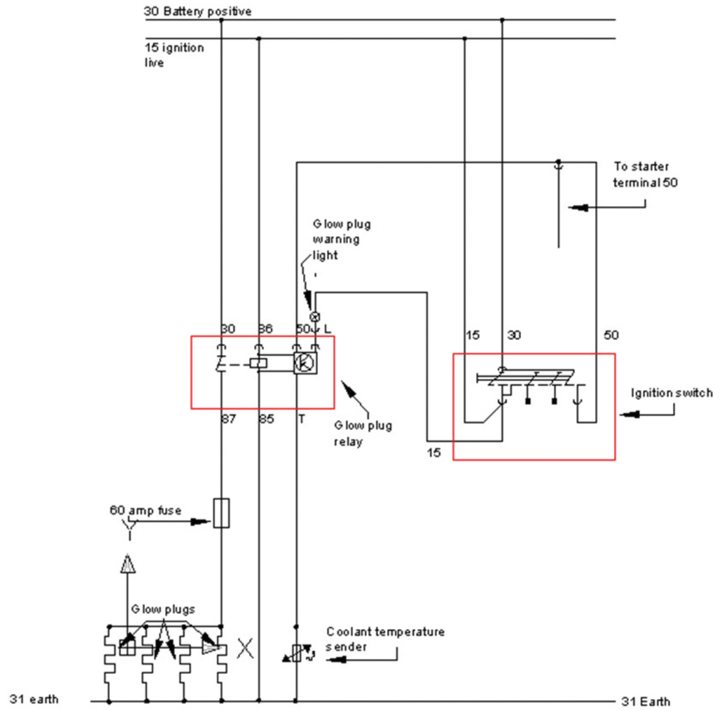
Key Learning Points

- Structure and operation of simple glow plug circuit

16.1 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 1000°C.



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.

17.0 Testing the Glow Plug Circuit and Plugs

Key Learning Points

- Use of manufacturer's recommended procedures for basic testing of the operation of glow plug circuits and measuring the electrical resistance of the glow plugs

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

17.1 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. 1

Technical Data	
Resistance	0,4Ω approx..

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

Checking Pre-Heating- Fig. 2

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.

Fig. 1

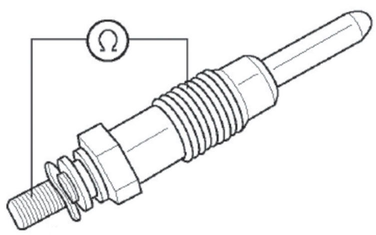


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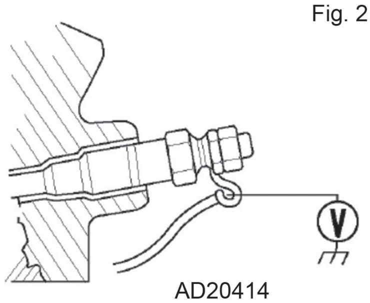
Fig. 2



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18.0 Checking Idle Speed on a C.I. Engine

Key Learning Points

- Use of recommended procedures for checking (and adjusting where appropriate) the idle speed on a C.I. engine

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

19.0 NCT/DoT VTM Requirements

Key Learning Points

- Use of data manuals/manufacturer's manuals
- NCT/DoT VTM requirements applicable to the diesel fuel system and compression ignition engine emissions

19.1 NCT Requirements

Please refer to Item 2 and 3 of NCT manual 2004.

20.0 Checking Emissions from a C.I. Engine

Key Learning Points

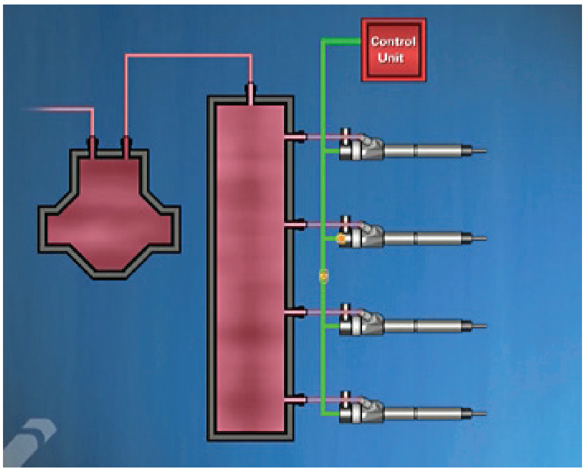
- Emissions checked using analyser manufacturer's recommended procedures

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

20.1 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:

- 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.
- Fuel injector operation: Including the timing rate and volume of fuel injected.
- Glow plugs and heater elements: Control of pre-heating of the intake air to support quick cold starting and reduced cold run emissions.
- Exhaust emissions: Analysis of exhaust gas to determine combustion efficiency and pollutants.
- And the data bus: An electronic communications network that allows exchange of data between computers - necessary for efficient operation and fault diagnosis.

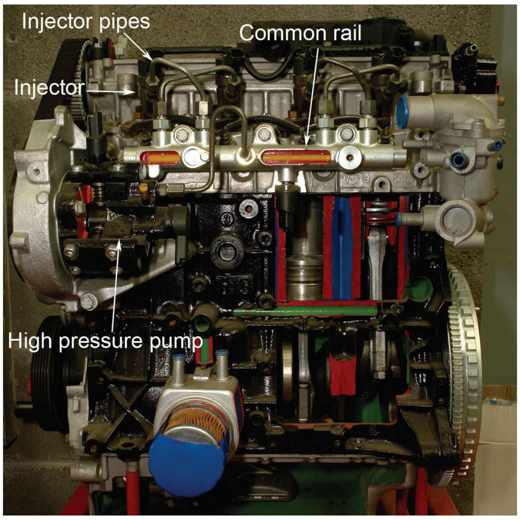
Other inputs monitored include:

- 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

20.2 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.

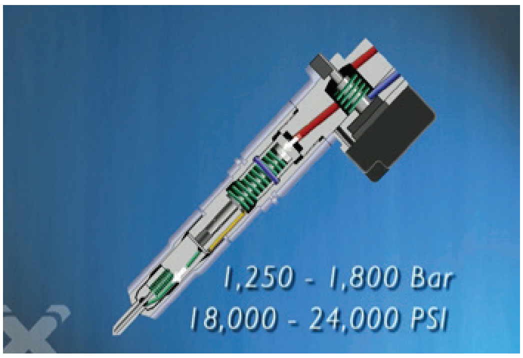
Diesel fuel injectors used in Common Rail injection systems operate differently to conventional fuel injectors used in the jerk pump system where the plungers are controlled by the camshaft position and speed. Some common rail injectors are controlled by a magnetic solenoid on the injector. Hydraulic 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.

20.3 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.



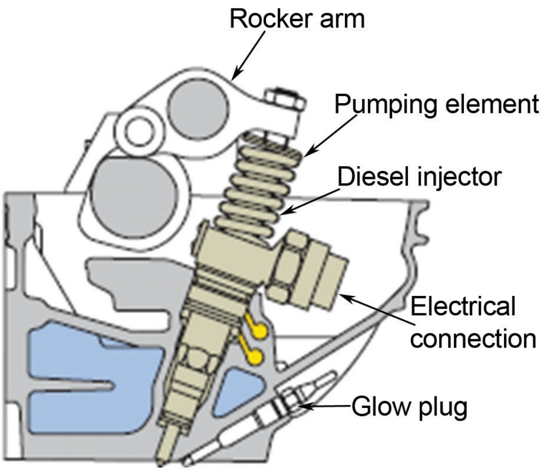
The injectors are controlled by a Power train Control Module or PCM. Although the PCM controls the duration of fuel injection pulses based on a range of inputs oil from a high-pressure oil pump hydraulically actuates the injectors.

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.

20.4 PD Pumpe Düse Pump Unit Injection Systems

Pumpe Düse - means 'pump injector or unit injector'

The injector and pump are integrated into a single Pumpe Düse unit. Each cylinder has its own Pumpe Düse unit mounted in the cylinder head and operated by the camshaft, injecting fuel directly into the combustion chamber at pressures up to 30,000psi. It has an Electronic Control Module or ECM and an electric pump as the primary fuel delivery system.



Operating of the Pumpe Düse system

The Crankshaft of the engine drives a pump camshaft, with an equal number of cams as the number of pistons, which is located to one side of the engine as opposed to the top in OHC engines. Each cam drives a Unit Injector. The Unit Injector works on the principle of Hydraulics using a small mechanical pump to pressurise fuel to very high levels currently up to 30,000psi.

The Unit Injector is basically a piston driven by the cam below in a small cylinder. There is a fuel inlet port that opens as the piston slides down, delivering fuel under pressure into the cylinder from an electric pump. As the cam turns, the port closes and the fuel is pressurised further ready to be released by the electronic actuator that opens and closes by the ECM. The actuator then is able to deliver fuel from the Unit Injector into the combustion chamber at very high injection pressures in various injection modes and programs.

Self Assessment

Q1: Diesel engine governors control engine speed by varying the: (Tick one box only)

- ❑ 1. Throttle position
- ❑ 2. Fuel quantity injected
- ❑ 3. Injection sequence
- ❑ 4. Injection timing

Q2: Diesel engines are fitted with governors to control engine speed. Why is this? (Tick one box only)

- ❑ 1. The engine could over rev and cause damage to both the internal and external components
- ❑ 2. The engine could over rev and cause damage to the external components
- ❑ 3. The vehicle could go too fast
- ❑ 4. The engine could over rev and cause damage to the internal components

Q3: The main difference in design between direct and indirect injection in diesel engines is that: (Tick one box only)

- ❑ 1. Indirect injection injects into the inlet manifold
- ❑ 2. Direct injection uses a flat piston
- ❑ 3. Indirect injection uses a separate chamber
- ❑ 4. Direct injection needs a glow plug for cold starting

Q4: In the Common Rail Diesel Injection System what is the other name given to the rail? (Tick one box only)

- ❑ 1. The injector
- ❑ 2. The accumulator
- ❑ 3. The Electronic Diesel Control unit
- ❑ 4. The jerk pump

Q5: In the Common Rail Diesel Injection System, how is the fuel fed to the injectors? (Tick one box only)

❑ 1. From the accumulator to the injectors via flexible injector pipes

❑ 2. From the accumulator to the injectors via metal injector pipes

❑ 3. From the pump to the injectors via metal injector pipes

❑ 4. From the pump to the injectors via flexible injector pipes

Q6: In the HEUI system of diesel fuel injection, what does HEUI stand for? (Tick one box only)

❑ 1. Hydraulically actioned, electronically controlled Unit Injector

❑ 2. Hydraulically stimulated, electrically actuated Unit Injector

❑ 3. Hydraulically actuated, electronically controlled Unit Injector

❑ 4. Hydraulically stimulated, electronically functioned Unit Injector

Q7: Injectors for diesel engines spray fuel into the: (Tick one box only)

❑ 1. Intake manifold

❑ 2. Air cleaner

❑ 3. Exhaust manifold

❑ 4. Combustion chamber

Q8: In a diesel fuel system there are normally two fuel lines from the tank to the system components, why? (Tick one box only)

❑ 1. One is a feed line and one is a lubrication line

❑ 2. When more fuel is required the second line supplies it

❑ 3. To vent the system

❑ 4. One is a feed line and one is a return line for excess fuel used for lubrication to be returned to the tank

Q9: What does the sedimenter do? (Tick one box only)

❑ 1. Mixes water with the fuel to aid combustion

❑ 2. Allows the driver to see when there is water in the fuel system

❑ 3. Separates water from the diesel fuel and drains the water from the system to prevent damage

Q10: How often is the sedimenter drained? (Tick one box only)

❑ 1. At regular servicing intervals

❑ 2. Never, it is designed to self clean

❑ 3. Whenever the fuel tank is filled

❑ 4. Once a year

Q11: What controls the governor in a mechanical governor arrangement? (Tick one box only)

❑ 1. Centrifugal force

❑ 2. Hydraulic pressure

❑ 3. Engine speed

❑ 4. Fuel flow

Q12: What controls the governor in a hydraulic governor arrangement? (Tick one box only)

❑ 1. Centrifugal force

❑ 2. Hydraulic pressure

❑ 3. Fuel flow

❑ 4. Engine speed

Q13: In the HEUI system of diesel fuel injection, how are the injectors actuated? (Tick one box only)

❑ 1. They are hydraulically actuated and controlled electronically

❑ 2. They are electronically actuated and hydraulically controlled

Q14: What drives the plunger type lift pump?
(Tick one box only)

❑ 1. A gear on the engine camshaft

❑ 2. A timing belt

❑ 3. An eccentric on the engine camshaft

❑ 4. A cam inside the injection pump

Q15: Holes may be drilled in the crankshaft between the main bearing journals and the crankpins to:
(Tick one box only)

❑ 1. Eliminate stress

❑ 2. Assist crankshaft cooling

❑ 3. Carry oil to the big end bearings

❑ 4. Reduce torsional vibration

Q16: Pintle-type diesel fuel injectors spray fuel:
(Tick one box only)

❑ 1. Into the inlet manifold

❑ 2. Into an open combustion chamber

❑ 3. Onto the spark plug

❑ 4. Into the pre-combustion chamber

Q17: In a 4-stroke diesel engine, how many power strokes are produced in two revolutions of the crankshaft?
(Tick one box only)

❑ 1. One

❑ 2. Two

❑ 3. Three

❑ 4. Four

Q18: In-line fuel injection pumps in a diesel fuel system:
(Tick one box only)

❑ 1. Have one pumping element for all cylinders

❑ 2. Have one pumping element per cylinder

❑ 3. Are connected to a throttle butterfly by a cable linkage

❑ 4. Have a vane pump to raise fuel injection pressure

Q19: Rotary fuel injection pumps in a diesel fuel system: (Tick one box only)

- ☐ 1. Have a vane pump to raise fuel injection pressure
- ☐ 2. Have one pumping element for all cylinders
- ☐ 3. Have one pumping element per cylinder
- ☐ 4. Are connected to a throttle butterfly by a cable linkage

Q20: In-line fuel injection pumps in a diesel fuel system are also know as: (Tick one box only)

- ☐ 1. Jerk type injection pumps
- ☐ 2. DPA type injection pumps
- ☐ 3. Rotary type injection pumps
- ☐ 4. CP type injection pumps

Q21: In a diesel fuel system, a leak-off rail returns excess fuel from the injectors to the: (Tick one box only)

- ☐ 1. Fuel tank
- ☐ 2. Fuel injection pump
- ☐ 3. Inlet manifold
- ☐ 4. Engine crankcase

Q22: Diesel engine speed is controlled by: (Tick one box only)

- ☐ 1. The quantity of air drawn into the engine
- ☐ 2. The quantity of fuel injected into the engine
- ☐ 3. The ignition timing
- ☐ 4. Adjusting camshaft timing

Q23: Conventional diesel fuel injectors for direct and indirect injection systems are operated by: (Tick one box only)

- ☐ 1. Air pressure
- ☐ 2. An electrical solenoid
- ☐ 3. Fuel pressure
- ☐ 4. A spring and rocker assembly

Q24: The ignition quality of diesel fuel is determined by: (Tick one box only)

❑ 1. Octane number

❑ 2. Octane rating

❑ 3. Compression rating

❑ 4. Cetane number

Q25: A hand-priming pump is fitted to diesel engine fuel systems to: (Tick one box only)

❑ 1. Bleed air from the system

❑ 2. Clear fuel blockages in the return line

❑ 3. Check injector operation

❑ 4. Prime the fuel for cold-starting

Q26: In a diesel fuel system, glow plugs are used in some engines and they are normally located in the: (Tick one box only)

❑ 1. Exhaust manifold, to promote cleaner burning

❑ 2. Intake manifold, to vaporize the air-fuel mixture

❑ 3. Combustion chamber, to raise the air temperature

❑ 4. Fuel filters, to vaporize the fuel

Q27: In a diesel fuel system, when glow plugs are used in some engines and they are normally associated with what type of injection system: (Tick one box only)

❑ 1. Direct injection engines

❑ 2. Indirect Injection engines

❑ 3. Pressure time injection engines

❑ 4. Detroit Diesel engines

Q28 Main bearings: (Tick one box only)

❑ 1. Support the camshaft in the cylinder block

❑ 2. Join the connecting rod to the crankshaft

❑ 3. Support the crankshaft in the cylinder block

❑ 4. Join the connecting rod to the piston

Q29: The intake valves in a 4-stroke diesel engine are normally larger that the exhaust valves. (Tick one box only)

❑ 1. True

❑ 2. False

Suggested Exercises

- Use an electronic data facility to procure manufacturer's appropriate data for use with practical exercises
- Remove and replace a diesel fuel filter and bleed the system
- Dismantle a diesel fuel injector identify the components and reassemble
- Check the spray pattern of a diesel fuel injector and report on condition
- Test a glow plug
- Check the idle speed on a C.I. engine

Training Resources

- Compression ignition vehicles/operational training unit engines sectioned compression ignition engine data manuals manufacturer's manuals NCT/DoT VTM manual video/ multimedia resources
- Selection of diesel fuel injection system components including assorted injectors rotary/distributor-type injection pumps sectioned fuel filters sheathed-element glow plugs glow plug relays
- Exhaust gas extractors
- Multimeters
- Absorbent material for spillages
- Injector test equipment
- Tachometers for C.I. engines barrier cream
- Latex gloves eye protection
- Appropriate sealed diesel fuel storage containers and fire extinguishers

Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- http://www.cdxglobal.com/
- http://auto.howstuffworks.com/
- http://www.autoshop101.com/
- http://www.cdxetextbook.com/
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.

Notes

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