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diesel fuel systems

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- Fuel injection systems
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- Fuel filters
- Injectors
- Types of injectors
- Distributor injection pumps: axial type
- Governor for axial pumps
- Complete axial distributor pump
- Distributor injector pumps: radial type
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- Injectors for common-rail systems
- Basic in-line injection pumps
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The correct operation of a diesel engine depends on its fuel injection system, which must supply the combustion chambers with just the right amount of fuel at the right time. The parts of the injection system that do this are made with a high degree of accuracy and operate with very small clearances.

This chapter will cover diesel fuel systems in general and also provide an understanding of the different types of injection systems – what they are and how they function.

Diesel fuel systems: general

The locations of the parts of a diesel fuel system for a light commercial vehicle are shown in Figure 16.1. This has a fuel-supply system and an injection system. Similar systems are used in four-wheel-drive vehicles and in some passenger cars.

A schematic diagram of the system is shown in Figure 16.2. The system includes the following parts, although all these parts are not in the diagram.

1. *Fuel tank* – to hold distillate.
2. *Fuel feed pump* – to supply fuel from the fuel tank to the injection pump.
3. *Fuel filter* – to filter minute particles from the fuel.
4. *Sedimenter* – to filter out water that might enter or condense in the system.
5. *Injection pump* – to deliver fuel at high pressure to the injectors at the right time.
6. *Injector pipes* – to connect the injection pump to the injectors.
7. *Injectors* – to spray fuel into the combustion chambers.
8. *Overflow and leak-off pipes* – to return excess fuel from the injection pump and the injectors to the tank.
9. *Governor or ECV* – to control the engine speed.
10. *Control lever on the governor or accelerator pedal sensor* – connected to the driver's accelerator.

System operation

The system operates in the following way:

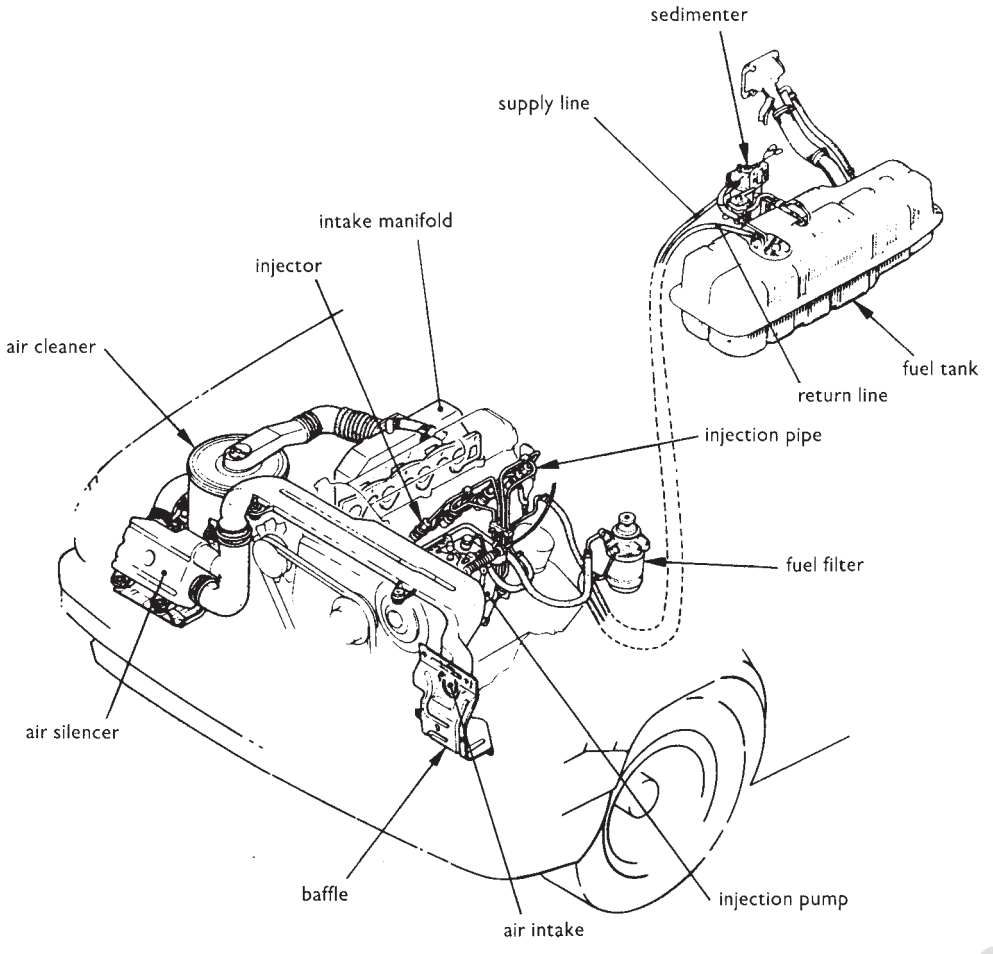


Figure 16.1 *Location of the parts of a diesel fuel system in a light commercial vehicle* FORD

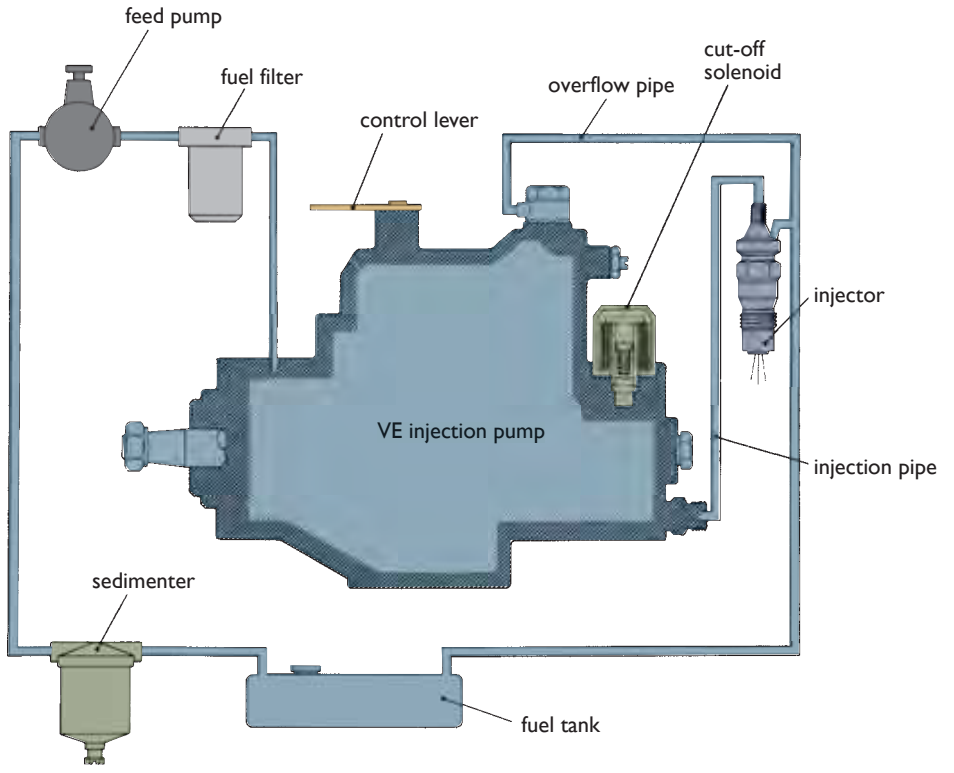


figure 16.2 *Schematic arrangement of a fuel system with a distributor-type injection pump* ZEXEL

1. Fuel taken from the tank by the feed (supply) pump passes through the sedimenter where water is filtered out.
2. Fuel passes from the feed pump through the fuel filter to the injection pump. The feed pump does not provide pressure, but keeps the system full.

   A hand-priming pump on the top of the filter is used to prime and bleed the system.
3. The injection pump has a pumping element that produces high pressure for the injectors. It also distributes high-pressure fuel to the injectors through the injector pipes.
4. The injectors are operated by the high-pressure fuel to spray fuel into the combustion chambers.
5. The injection pump has an internal vane pump (feed pump) to provide a low pressure and to keep the injection pump full. The feed pump supplies more fuel than is needed.
6. The surplus fuel is taken from the top of the pump through the overflow pipe back to the fuel tank. Circulation of the fuel cools and lubricates the injection pump and also bleeds air from the system.
7. The leak-off pipe on the top of the injectors carries a small quantity of fuel back to the fuel tank. This is fuel that leaks up inside the injector. It is used to lubricate and bleed the injector before being returned to the fuel tank.
8. The engine speed and power is controlled by the accelerator and linkage, which is connected to the pump governor.
9. The fuel cut-off solenoid that is fitted to the injection pump is used to stop the engine. When the engine switch is turned off, it cuts off the fuel to the pumping element.

Information: The system has two main functions – fuel supply and fuel injection. Some components are responsible for fuel supply and others are responsible for fuel injection.

Fuel injection systems

There are a number of different injection systems for diesel engines. The main difference is that they have different types of injection pumps, although some are electronically controlled.

The types of injection systems are:

1. distributor pump systems
2. common rail, or accumulator, systems
3. in-line injection pump systems
4. unit-type systems.

Distributor pump systems and common-rail systems are the most commonly used on engines in passenger and light commercial vehicles. In-line systems are now used mainly on medium to heavy diesel engines and unit-type injection systems are used on heavy diesels.

Distributor pump systems

The system previously described has an axial-type distributor pump. There are two designs of distributor pumps: *axial pumps* and *radial pumps*. These are the types that are used on most light diesel engines. Distributor pumps are designed for engines that operate at relatively high speeds. They have a single pumping element, regardless of the number of cylinders of the engine. The pumping element and the distributing arrangement are designed to suit the number of cylinders of the engine.

The main difference in these two injection pumps is the design of the high-pressure pumping element. As the names suggest, the axial type has a pumping plunger that acts *axially*, that is backwards and forwards within the pump.

The radial type has a pumping element with plungers that act *radially*, that is inwards and outwards in relation to the centreline of the pump shaft.

Reference: The diagram in Figure 16.2 shows one injector only; a four-cylinder engine would have four injection pipes and four injectors.

Common rail systems

The arrangement of a common rail injection system is shown in Figure 16.3. This has a low-pressure electric pump in the fuel tank and a high-pressure fuel pump that is driven by the engine. The low-pressure pump delivers fuel to the high-pressure pump, where the pressure is increased to injection pressure. A fuel line connects the pump to the common fuel rail, and injector pipes connect the common rail to the injectors.

The injectors are fitted with an electric solenoid that is controlled by an electronic control unit (ECU). Electronic control opens and closes the injectors so that they deliver a specified quantity of fuel at the right time.

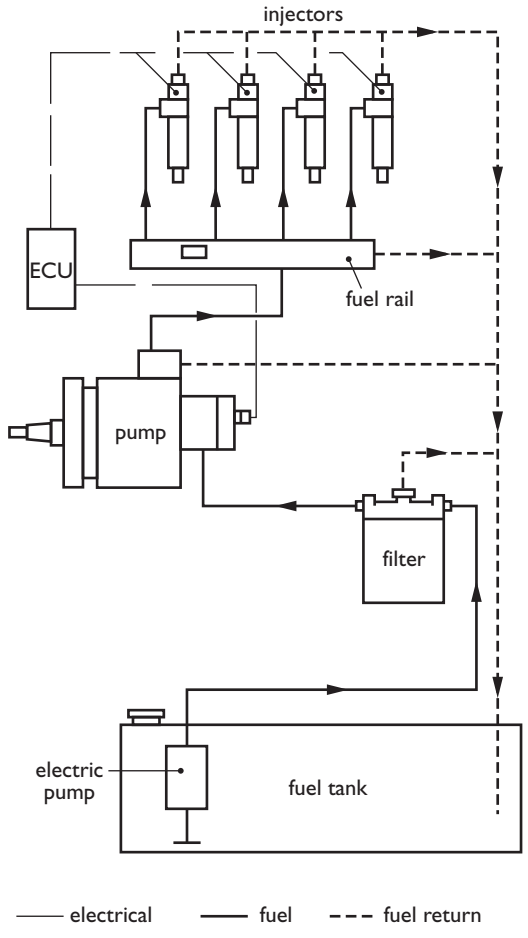


Figure 16.3 *Arrangement of a common rail fuel injection system for a four-cylinder engine*

The system has a return line that returns surplus fuel from the top of the injectors, from the high-pressure pump and from the filter.

In-line injection pump systems

The arrangement of a system with an in-line injection pump is shown in Figure 16.4. This has six separate pumping elements, one for each cylinder of the engine. Injection pipes connect the pumping elements to the injectors. In-line pumps are used with some light diesel engines and with many engines of commercial vehicles.

The in-line system shown has a supply pump mounted on the side of the injection pump. It takes fuel from the tank and pumps it through the filters to the injection pump. It also has an overflow line from the top of the filter to the tank, and a leak-off pipe from the injectors. The fuel flow in the system is marked on the diagram.

Unit injector systems

In these types of systems, the functions of the injection pump element and the injector are combined

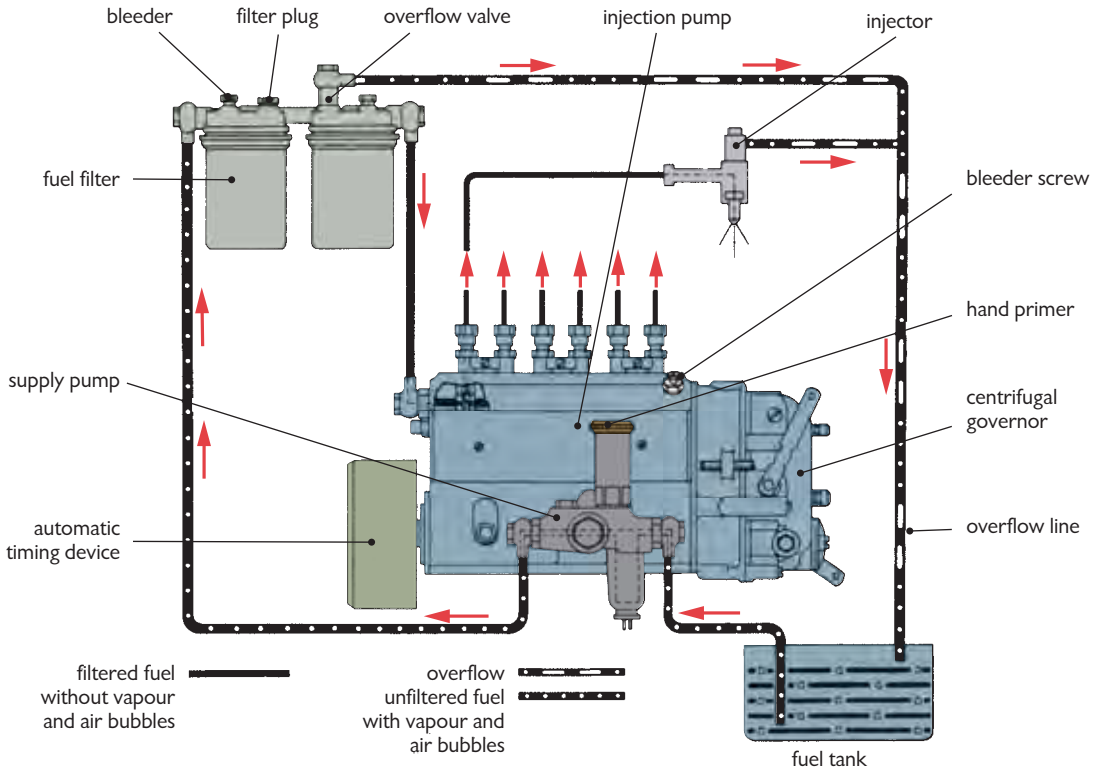


Figure 16.4 *Diagram of a fuel system with an in-line injection pump* BOSCH

within the injector itself. This enables the injectors to provide a high-pressure charge of fuel and also to inject it as a fine spray into the combustion chamber.

The injector is operated by a rocker arm and pushrod by a cam on the engine's camshaft. Each cylinder has its own injection unit.

The diagram in Figure 16.5 shows this type of arrangement. Fuel is taken from the tank by a transfer pump. It passes first through the primary filter, then through the pump to the secondary filter, and on to the injector. At the appropriate time, the plunger of the injector is operated by the rocker arm. This pressurises the fuel in the injector and the correct amount is sprayed into the combustion chamber.

In this system, fuel at a low pressure is being constantly circulated through passages in the cylinder head. This supplies the injectors with fuel and returns the surplus to the fuel tank.

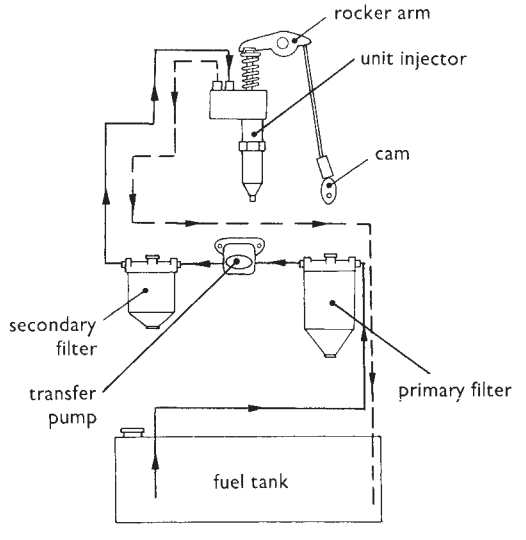


Figure 16.5 *Arrangement of a diesel fuel system with a unit injector*

Fuel supply pumps

All diesel fuel systems have some form of supply pump that takes fuel from the tank and delivers it to the injection pump or, in the case of unit injectors, directly to the unit injector. Vane pumps, diaphragm pumps, plunger pumps and gear pumps are all used, but this depends on the type of system.

Information: Pumps that supply the low-pressure fuel are referred to as *supply pumps feed pumps, lift pumps* or *transfer pumps.*

Vane pumps

Vane pumps are used with distributor-type injection pumps. The vane pump is located inside the injection pump housing. It is used to take fuel from the fuel tank and supply it to the high-pressure pumping element.

The vane pump is driven by the injection pump shaft (Figure 16.6). It has a rotor that is mounted off-centre in the pump housing. Slots in the rotor carry the vanes, which slide backwards and forwards as the rotor turns. Fuel taken into the pump inlet is carried around between the vanes and the body of the pump and discharged from the outlet.

Handy hint: Vane pumps used with distributor-type pumps are usually referred to as feed pumps.

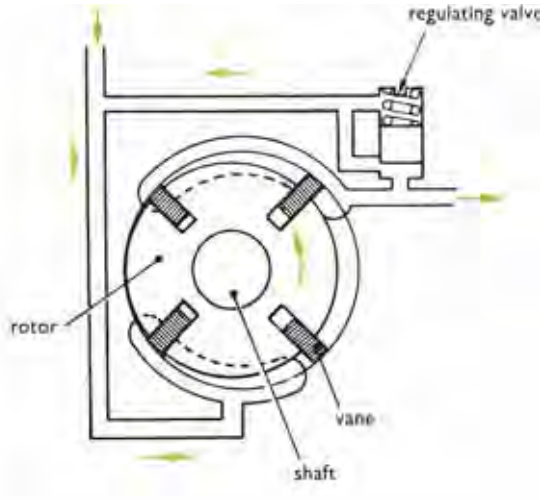


Figure 16.6 *Arrangement of a vane-type feed pump, used with a distributor-type injection pump* ZEXEL

Plunger pumps

Plunger pumps are used with in-line injection pumps. They are often fitted to the side of the injection pump and operated by a cam on the injection pump's camshaft (Figure 16.7).

The cam moves the plunger backwards and forwards to take fuel in through the suction valve and pump it out through the discharge valve, so maintaining a flow of fuel.

Figure 16.8 illustrates plunger pump operation, as follows:

1. *Upstroke*. Fuel is forced through the discharge valve into the outlet and also into the outer chamber under the plunger.

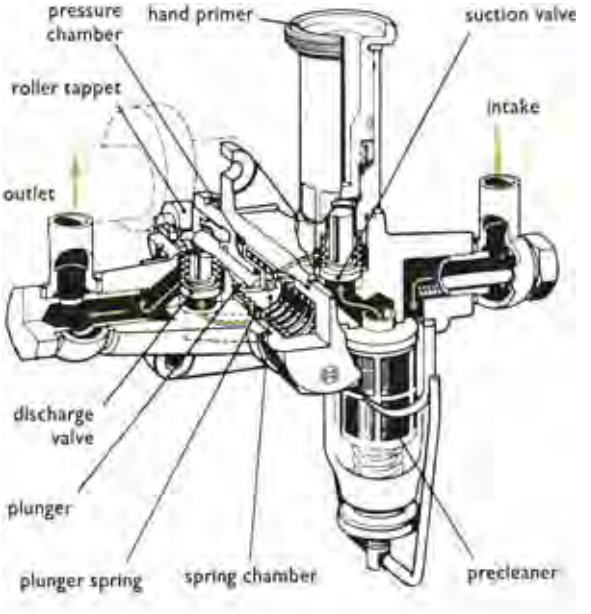


Figure 16.7 *Plunger fuel supply pump* BOSCH

2. *Downstroke*. The plunger is forced down by the spring, and fuel from the outer chamber is pumped through the outlet. At the same time, fuel is also taken into the inner chamber through the suction valve.
3. *Reduced stroke*. When the pressure beneath the plunger exceeds the spring pressure on top of the plunger, the stroke will be reduced. The plunger will be held away from the pushrod, and its stroke will be reduced until the pressure under the plunger drops. This is how pump pressure is controlled.

Priming pumps

Priming pumps are used during servicing to fill the system with fuel and to bleed air from the pump and injector pipes.

A hand-priming pump is fitted to the top of the supply pump on in-line injection systems. This is operated by unscrewing the plunger and then moving it up and down by hand. In other systems, a separate hand pump can be fitted, or it can be combined with a filter (as shown in Figure 16.12).

Electric pumps

The common rail system uses an electric fuel pump (Figure 16.9). This is located inside the fuel tank and is used to supply low-pressure fuel to the main high-pressure pump.

The electric pump consists of an electric motor with permanent magnet fields connected to a roller-cell pump. Fuel drawn into the pump passes through the body of the pump before leaving the tank.

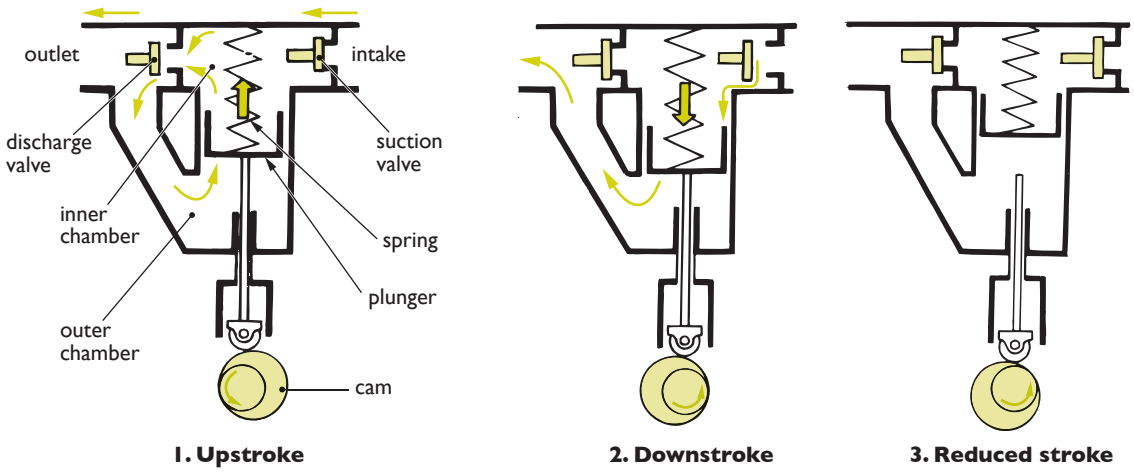


Figure 16.8 *Operation of a plunger-type supply pump* ZEXEL

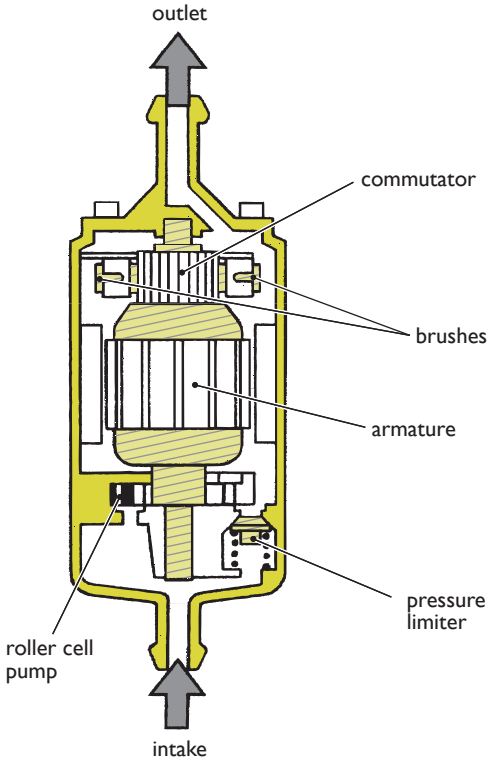


Figure 16.9 *Electric fuel pump for a common-rail injection system* BOSCH

A pressure limiter, in the form of a spring-loaded valve, opens when operating pressure is reached. This limits the pressure in the low-pressure side of the system.

Fuel filters

Filtering of diesel fuel is most important because of the very small clearances that exist between the working parts in the injection pump and the injectors. Diesel fuel must be clean.

The clearance between some injection parts is as little as 2 to 4 microns. A micron is one-thousandth of a millimetre (0.001 mm). To get some idea of the size of the dust particles that need to be filtered out, Figure 16.10 compares the size of dust particles with a human hair. A medium-sized particle that can be floating in the air has about one-tenth the diameter of the hair.

Safety tip: Care must be taken so that fuel put into the tank of a vehicle is not contaminated by anything, including water.

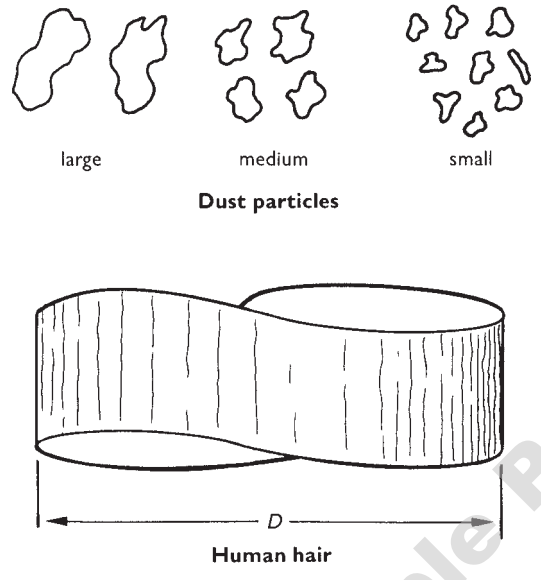


Figure 16.10 *Size of dust particles compared with human hair – D diameter of hair*

There are a number of different designs of filters, and they can be located in different parts of the system. Filters can be fitted between the supply pump and the tank, or between the supply pump and the injection pump.

Faulty sealing of a filter on the suction side of a supply pump will allow air to enter and fuel to leak, while faulty sealing on the pressure side will allow fuel to leak.

Filter with separate element

Figure 16.11 shows a fuel filter with a replaceable element. The filtering material is made of pleated paper which will filter out very small particles.

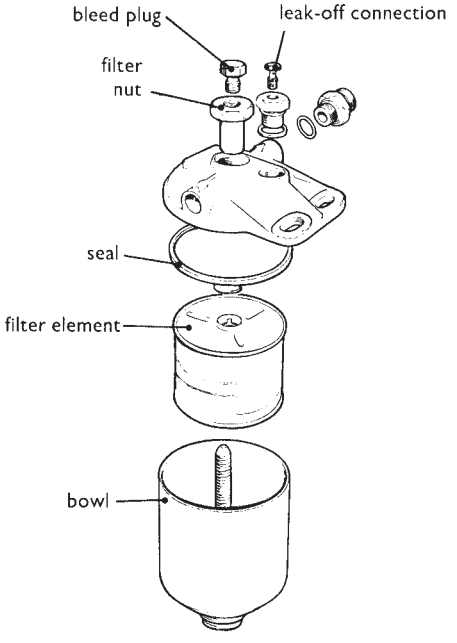
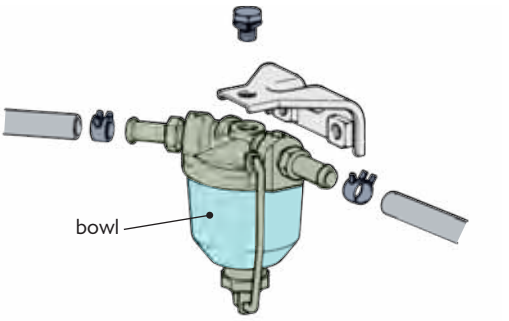
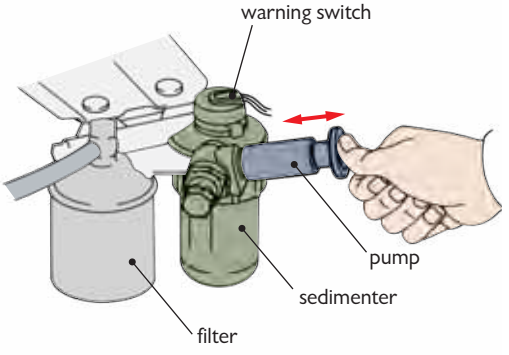


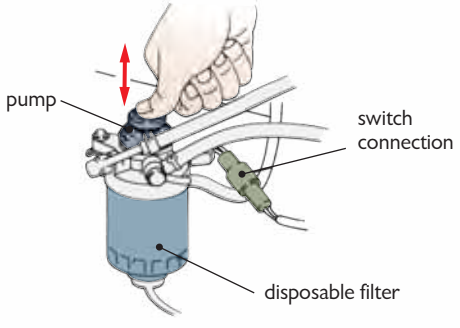
Figure 16.11 *Fuel filter with replaceable element* LUCAS/CAV



(a) Filter with glass bowl



(b) Filter and sedimenter



(c) Sedimenter

Figure 16.12 *Types of diesel fuel filters* TOYOTA

Filter with glass bowl

The filter in Figure 16.12(a) has a glass bowl and a filtering element. The filter can be checked for deposits or water by viewing through the clear glass bowl. The bowl can be removed for cleaning.

Water and sediment filters

Sedimenters, or sediment filters, are used to remove water and sediment. In Figure 16.12(b), a fuel filter and a sedimenter are used side by side. Any water in the fuel is removed by the sedimenter before it reaches the fuel filter. A warning light is switched on if the water level builds up in the bowl. The sedimenter shown is fitted with a hand-priming pump.

Sedimenter

Figure 16.12(c) shows a sedimenter that has a throw-away filter. It has a filter canister similar to an engine-oil filter. The sedimenter is serviced by fitting a new canister. This also has a hand-priming pump.

A sedimenter filters out water and small solid particles and these form sediment in the bottom of the filter bowl. Most sedimenters are fitted with a switch that operates a warning light when the water in the filter reaches a certain level. Water in a system can block filters and will cause considerable damage if it reaches the injection pump.

The sedimenter in Figure 16.13 has a water-level detector. If the water level becomes too high, the

Technical terms

Injection pump, injector pipe, injectors, governor, distributor pump, radial pump, common rail, in-line pump, unit injector, supply pump, lift pump, feed pump, transfer pump, vane pump, plunger pump, priming pump, leak-off pipe, cut-off solenoid, pumping element, filtration, micron, filter element, sediment, sedimenter, injector nozzle, dribble, pintle, sac hole, seat hole, cam disc, cam ring, delivery valve, barrel, plunger, effective stroke, centrifugal force, flyweights, axially, radially, ECU, pump element, jerk-type pump, phased, control rod, rack, spill port, fuel gallery, helix

Review questions

1. Name the main parts of a diesel fuel system.
2. Name three common types of injection pumps.
3. What is the purpose of a feed or supply pump?
4. What types of pumps are used for fuel feed or supply?
5. Why is filtration important in a diesel fuel system?
6. What types of filters are used in a diesel fuel system?
7. How is water filtered from a diesel fuel system?
8. Why is a priming pump fitted to a diesel fuel system?
9. What is a sedimenter?
10. Explain how a sedimenter works.
11. Name the main parts of an injector.
12. How are injectors secured to the cylinder head?
13. Name some of the types of injector nozzles.
14. What is an axial-type distributor injection pump?
15. Explain briefly what the plunger of an axial-type distributor pump does during a pumping stroke.
16. What produces movement of the plunger in an axial-type distributor pump?
17. How is fuel delivery controlled in one type of distributor pump? (Refer to one of the illustrations.)
18. Using the appropriate illustration, explain briefly how a mechanical governor operates.
19. Name the main parts of a radial-type injection pump.
20. Name the main parts of a common-rail injection pump.
21. What is the purpose of the common rail in an injection system?
22. How does the injector of a common-rail system differ from most other injectors?
23. Name the main parts of a pumping element of an in-line injection pump.
24. What is meant by the effective stroke of a pump plunger?
25. How is the quantity of fuel that is delivered by a pumping element of an in-line pump controlled?
26. What is the purpose of a delivery valve?
27. What is the function of the control rod of an in-line pump?
28. How is electronic control used for a diesel injection system?