Service Bulletin Trucks

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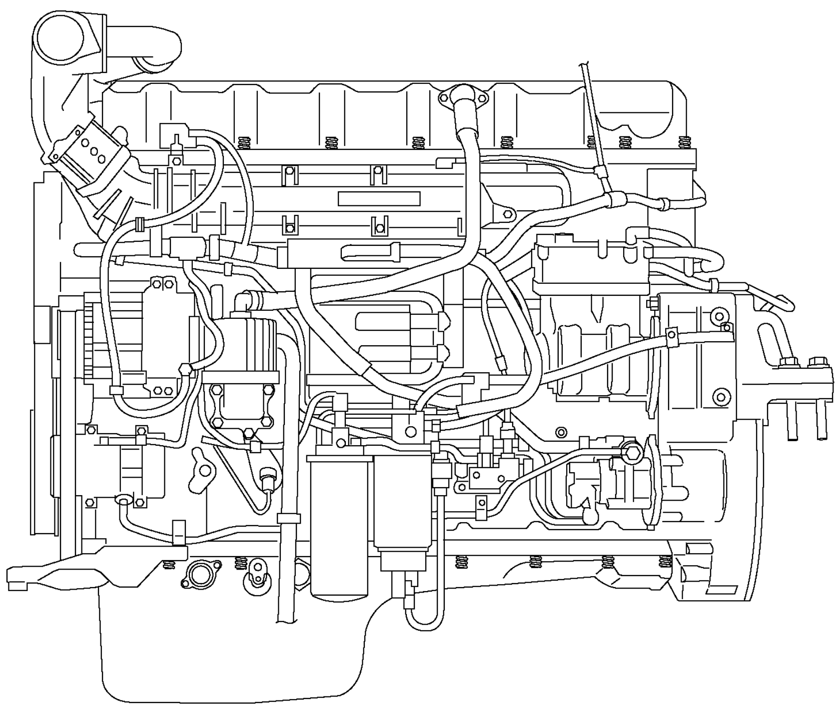
Fuel System
Design and Function
D13F

Fuel System, Design and Function



W2005843

This information covers the design and function of the fuel system on the Volvo D13F engine.

Contents

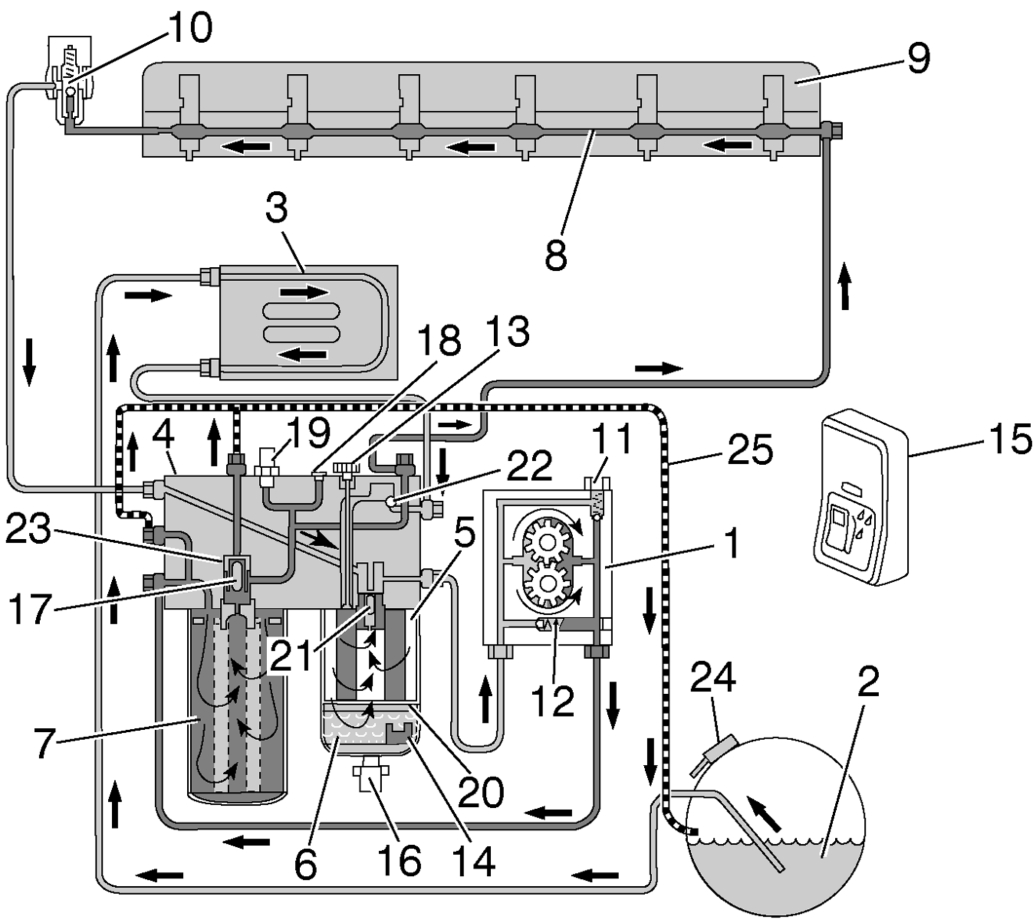
Note: Information is subject to change without notice.
Illustrations are used for reference only and can differ slightly from the actual vehicle being serviced. However, key components addressed in this information are represented as accurately as possible.

Design and Function

Fuel System

When fault tracing, it is important to understand the function of the system in order to avoid replacing non-defective components.

System Function



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Fuel is drawn up the fuel lines by the supply pump (1) through the pickup tube in the fuel tank (2) in through the Engine Electronic Control Unit (EECU) cooling coil (3), and into the fuel filter housing (4). The fuel filter housing is equipped with a pre-filter (5) and a water separator (6), where fuel is filtered through the primary filter that separates any water from the fuel.

The supply pump (1) forces the fuel into the fuel filter housing through the main filter (7) to a cylinder head longitudinal fuel gallery (8). This channel supplies each unit injector (9) with pressurized fuel by a circular groove around each unit injector in the cylinder head. The overflow valve (10) controls the fuel supply pressure to the unit injectors.

The return fuel from the overflow valve (10) is returned back to the fuel filter housing and is mixed with the fuel from the fuel tank in a channel within the fuel filter housing (4).

Supply Pump Valves

Two valves are located in the supply pump (1).

The safety valve (11) allows fuel to flow back to the suction side when the pressure becomes too high, e.g., if the fuel filter is blocked or is too restricted. The non-return valve (12) opens when hand-priming is used.

Automatic Bleeding

If air gets into the system, it is bled when the engine starts. During bleeding, the air is pressed out through the fuel filter housing over to the fuel tank through the return line (25). Bleeding for the filter replacement is controlled by valves (17) and (23).

Water Drainage

Draining water from the water separator (5) requires the following:

- The sensor (14) in the water separator indicates water in the fuel bowl.
- The engine is not running.
- The ignition key is in the ON position.
- The parking brake is applied.

When the switch (15) is depressed (located in the cab instrument panel), the drain valve (16) opens for about 15 seconds and drains the water. If additional drainage is needed, wait 6 minutes before repeating because the function is on a timer.

Manual Hand Pump

The manual hand pump (11) is located on the fuel filter housing and is used to pump fuel (when the engine is not running) after the fuel system has been drained for repair, etc. The non-return valve (22) for the hand-priming pump is also located in the fuel filter housing.

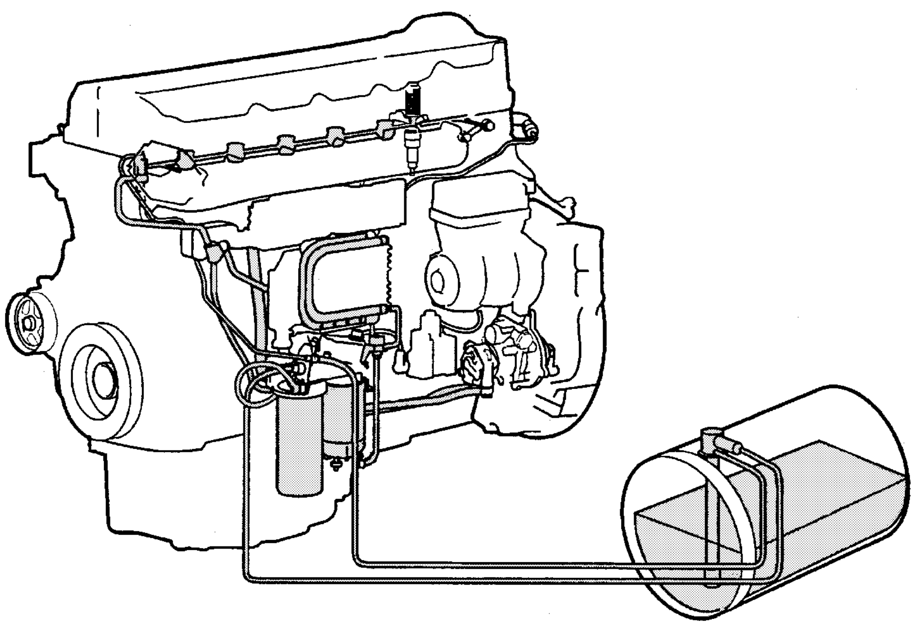
Other

The fuel filter housing eliminates the need to drain the fuel when replacing the filter. The valve pegs (17) and (21) close when the fuel filter is removed. It is not necessary to bleed the fuel system after replacing the filter, since this is performed automatically when the engine is started and runs for more than 2 minutes.

The plugged outlet (18) is fitted on the fuel filter housing. The outlet is used when measuring supply pressure after the fuel filter with an external pressure gauge. The pressure sensor (19) on the fuel filter housing monitors the supply pressure after the fuel filter. A fault code is displayed on the instrument cluster if the fuel supply pressure is less than the specified value.

A fuel heater (20) is available as an option. It is located in the lower part of the water separator. The fuel tank breather (24) prevents excessive vacuum in the fuel tank(s) which could possibly result in fuel starvation.

Fuel System Components



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Current Volvo diesel engines are electronically controlled and designed to meet today’s strict environmental standards. Meeting these standards requires optimum combustion. This demands, among other things, injecting the exact amount of fuel into the combustion chamber under very high pressure at precisely the correct time, depending on engine speed, load, temperature and other conditions.

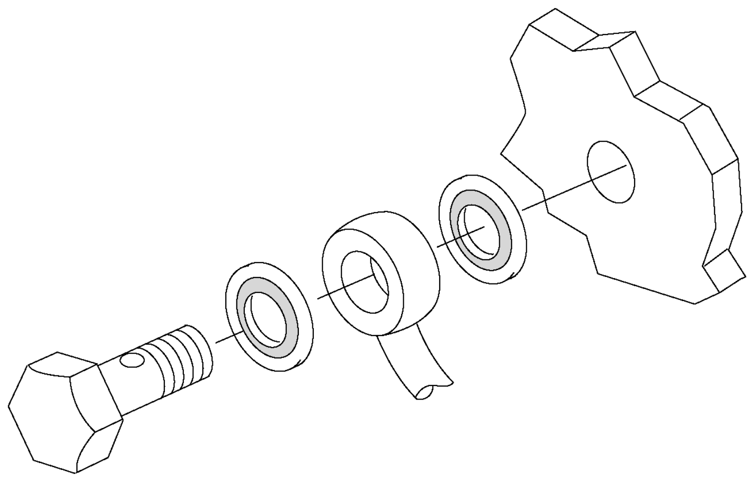
Totally mechanical injection systems cannot meet these demands and so requires that engines are equipped with an electronically controlled injection system. An Engine Electronic Control Unit (EECU) receives electrical signals from the accelerator pedal and a number of other sensors on the engine. These sensors provide speed, pressure and temperature signals, sent to the EECU, which in turn governs the fuel injection process. The EECU has a built-in diagnostic system which electronically detects and traces faults that might occur in the fuel system.

Each cylinder has four valves. Individual differences always occur between the cylinders in an internal combustion engine. The engine has a cylinder balancing system, the purpose of which is to even out the amounts of fuel between the cylinders. Cylinder balancing takes place with the engine running at idle speed, providing certain preconditions have been met.

Fuel Line Compression Fitting

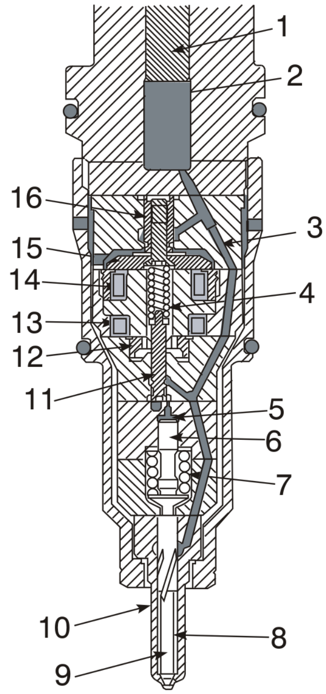
Always replace the fuel line compression sealing washers when:

- Troubleshooting for fuel aeration and/or
- Performing any service procedure that requires the removal of engine fuel lines.



Typical Compression Sealing Washers

Unit Injectors



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1. Pump Element	9. Needle
2. Pump Chamber	10. Nozzle
3. High Pressure Fuel Line	11. Needle Control Valve (NCV)
4. Return Spring	12. Needle Control Valve Armature
5. Needle Backing Chamber	13. Needle Control Valve Electrical Coil
6. Needle Control Piston	14. Spill Valve Electrical Coil
7. Needle Closing Spring	15. Spill Valve Armature
8. Needle Chamber	16. Spill Valve (SV)

Unit injectors for diesel engines have both injector pump element and the nozzle assembly in the same body. The pump stroke is activated by a camshaft lobe which rotates at one half crankshaft speed in 4 stroke engines. The pump stroke is always constant, but the delivery through the injection nozzle is controlled by an electrically operated solenoid valve, usually named a Spill Valve (SV). The SV is located between the high pressure fuel line and the low pressure fuel line. When the SV is closed, all the fuel from the pump chamber is forced through the nozzle and into the engine combustion chamber. When the SV is open, the fuel is routed into the low pressure fuel feed line and so no fuel passes through the nozzle. The SV is operated by the Engine Electronic Control Unit (EECU) by software and certain power stages capable of driving the solenoids.

The injected fuel quantity per pump cycle is determined by how long the SV is closed during the pump stroke. The start of injection, i.e., injection timing, is determined by when the SV is closed.

The injection pressure achieved is balanced out by a number of factors:

1 The pumping capacity (pump element diameter, cam rate) versus the restriction in the nozzle (the nozzle hole area).
2 The engine speed, i.e., fuel/sec from the pump chamber versus the nozzle hole area.
3 The nozzle opening pressure.

For a given unit injector/cam/nozzle specification, the injection pressure is well defined over the speed/load range for a specific engine. Engine exhaust emissions are very dependent on the fuel spray characteristics and are, to a large extent, influenced by the nozzle spray hold design and the injection pressure. Therefore, it is of great benefit to be able to change these parameters and today it is possible to vary at least one of them, namely the injection pressure. The method is to let the pressure build up to a desired level before opening the nozzle needle.

To make the nozzle opening freely adjustable, a second valve is used, the Needle Control Valve (NCV). The NCV is a three port, two position valve, located between the high pressure fuel line, the low pressure fuel line and a needle backing chamber. The valve controls the pressure in the backing chamber by either connecting the chamber to the high pressure line or to the low pressure fuel line. Pressure in the chamber exerts force on the back of the nozzle by the control piston. The diameter of the control piston is the same as the needle guide diameter so that when the needle is off the needle seat, pressure balance is achieved. When the needle is on the needle seat, the effective area on the lift side is reduced and, with the same pressure acting on both sides, there is a net force keeping the needle on the needle seat.

The force equation is:

- Pressure x control piston area plus spring force acts to keep the needle closed.
- Pressure x lift area acts to open the needle.

With the same pressure acting on both areas, the acting force is spring force plus the pressure force due to the difference of the two effective areas. This keeps the needle closed.

When the desired pressure in the needle chamber is achieved, the NCV is activated, closing the high pressure line to the back of the needle control piston and at the same time, connecting the back of the piston to the low pressure line. The high pressure on the back of the needle control piston is removed and the pressure on the lift side now overcomes the closing force from the needle closing spring and the needle opens.

In this way, the Needle Opening Pressure (NOP) can be varied between the preset spring NOP and the maximum pumping pressure. Practically, the levels used are between 250–1800 bar, to be compared with a common nozzle, using 250–350 bar opening pressure.

The influence on spray formation is such that the soot (particulate matter) formation is lowered with increased needle opening pressure while at the same time, NOx formation is increased.

By using a variable NOP over the speed/load range of the engine, it is possible to balance with trade-off between the particulate matter and NOx formation to achieve the best combination for each speed/load point and thus decrease engine exhaust emissions.

Injector Operational Phases

Fill Phase

During the filling phase, the pump plunger is on its way up, the camshaft lobe is passing its highest point and the rocker arm is on its way toward the camshaft base circle.

The fuel valve is open, allowing fuel to flow into the unit injector from the lower fuel gallery. Fuel flows into the cylinder head and the unit injector pump cylinder. Filling continues until the pump plunger reaches its upper position.

Spill Phase

The spill phase begins when the camshaft lobe forces the rocker arm to push the pump plunger down.

The fuel can now flow through the fuel valve, through the holes in the unit injector and out through the fuel gallery. The spill phase continues as long as the fuel valve is open.

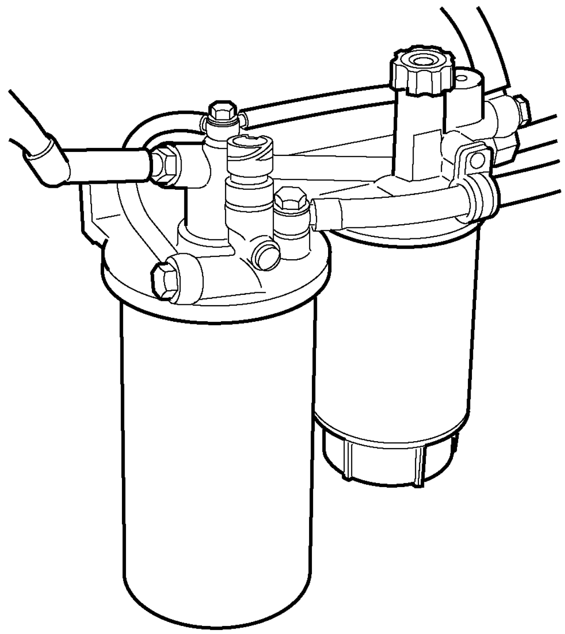
Injection Phase

The injection phase begins when the fuel valve closes. The camshaft lobe and rocker arm continue to press down on the pump plunger and injection occurs as the path through the fuel valve closes. The injection phase continues as long as the fuel valve is closed.

Pressure Drop Phase

The injection phase ends when the fuel valve opens and pressure in the unit injector drops below the nozzle opening pressure. The fuel flows through the open fuel valve, through the unit injector holes and out through the fuel gallery. Note that the fuel valve position (closed or open) determines when the injection phase begins and ends. The time during which the fuel valve is closed determines the amount of fuel injected at each pump stroke.

Fuel Filter



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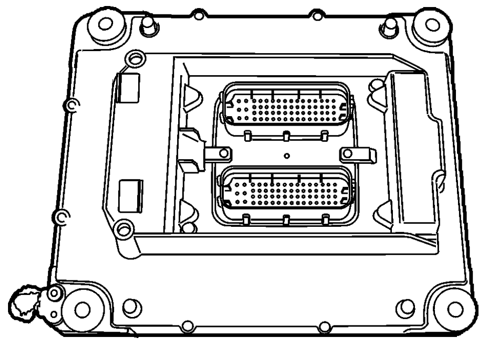
The system is equipped with a large fuel filter located on the left-hand side of the engine. The filter insert consists of a corrugated filter paper with a high resistance to water and very good filtering properties. In addition, a fine-gauge net filter on the fuel suction line in the fuel tank separates any possible solid impurities before the fuel is pumped up into the system.

Fuel Feed Pump

The capacity of the pump has been adapted to give the correct pressure and flow to the unit injectors. Filling the unit injectors requires relatively high pressure. The flow must be large enough to even out any fuel temperature differences in the cylinder head fuel gallery.

Engine Electronic Control Unit (EECU)



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The engine electronic control unit is the central part of the injection system. It is located on the left-hand side of the engine. The EECU receives continuous information from the accelerator pedal and from several other sensors on the engine. It calculates the amount and the time to inject fuel into the cylinders. Electrical wiring to the unit injectors transmits control signals to the injectors from the EECU.

The EECU uses the flywheel sensor to monitor engine rotation and engine speed variations during a revolution. This allows the EECU to ensure that each unit injector receives exactly the correct amount of fuel. The EECU stores information when a fault occurs or if something in the system is abnormal. Intermittent faults are also stored and can be traced at a later time.