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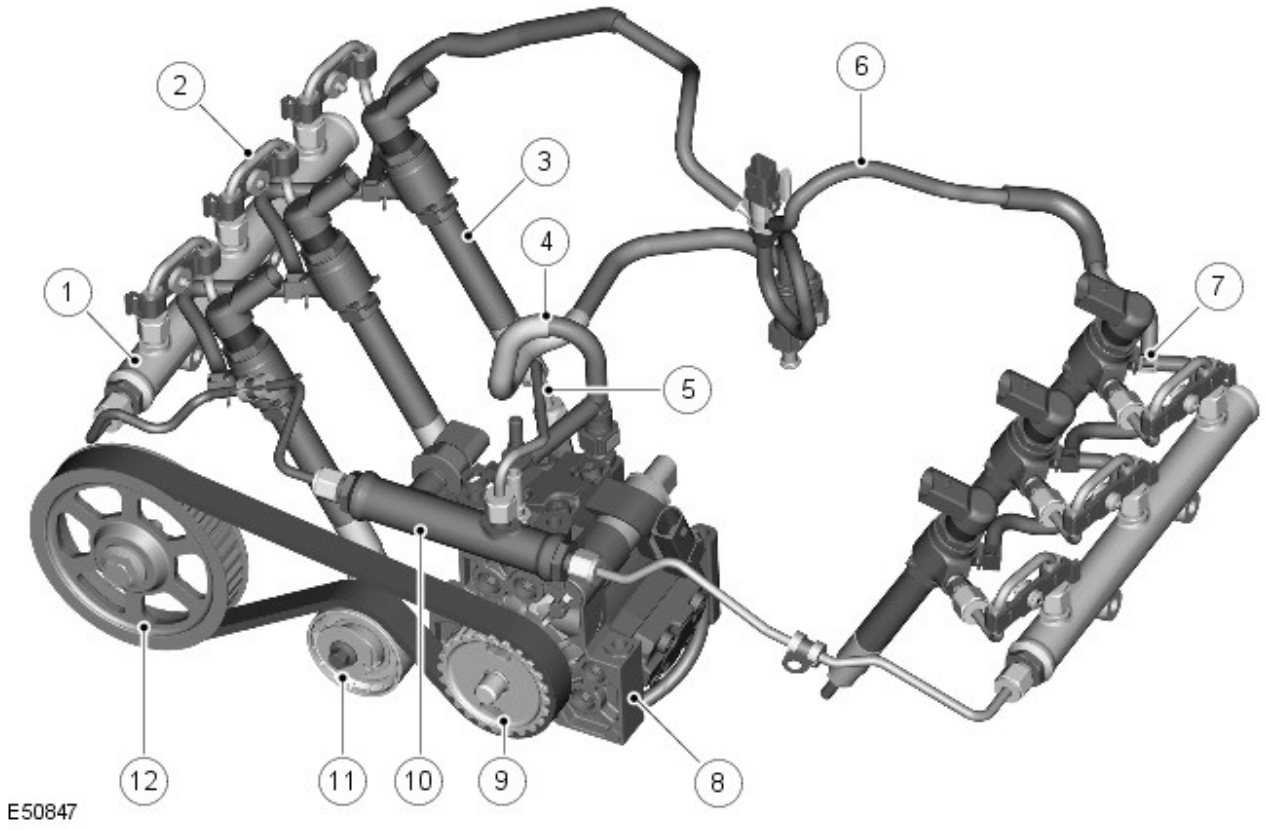
FUEL CHARGING AND CONTROLS – TDV6 2.7L DIESEL (G421108)

DESCRIPTION AND OPERATION

Component Locations



ITEM	DESCRIPTION
1	High-pressure (HP) fuel rail (2 of)
2	HP pipe - Fuel rail to injector (6 of)
3	Injectors (6 of)
4	Low Pressure (LP) pipe - Fuel return
5	HP pipe - High Pressure Pump (HPP) to fuel diverter rail
6	LP pipe - Injector leak-back
7	Connector to injector (part of 6)

8	HPP
9	HPP pulley
10	HP diverter rail
11	Rear Engine Accessory Drive (READ) belt tensioner
12	LH exhaust camshaft pulley

GENERAL

The TdV6 is equipped with a High-Pressure (HP) common rail fuel injection system. With this fuel injection process, a High-Pressure Pump (HPP) delivers a uniform level of pressure to the shared fuel lines (the common rails), which serve all six fuel injectors. Pressure is controllable, to the optimum level for smooth operation, up to 1650 bar.

The common rail system supports a pre-injection (pilot) phase, which reduces combustion noise and mechanical load.

Fuel injection pressure is generated independently of engine speed and fuel injection events.

The fuel injection timing and volume are calculated by the Engine Control Module (ECM), which then energizes the appropriate piezo actuated injector.

The common rail fuel injection system has the following features:

- High fuel injection pressures of up to 1650 bar for greater atomisation of fuel (increasing performance and lowering emissions)
- Variable injection to optimise combustion in all engine operating conditions
- Low tolerances and high precision throughout the life of the system

The fuel system is divided into 2 sub systems:

- Low-Pressure (LP) system
- HP system.

The LP system features the following components:

- In-tank fuel pump
- Fuel pressure regulator (integral to the fuel delivery module)
- Fuel filter
- Return pipes and fuel cooler

- Injector return pipes
- Fuel coolers (engine and vehicle)

The LP system pressure is regulated to 0.5 bar.

The HP system features the following components:

- HPP
- Common rails and diverter rail
- HP fuel pipes
- Injectors.

LP SYSTEM

IN-TANK FUEL PUMP

The electric fuel pump is located inside the fuel tank. Fuel is pumped from the tank via the in-tank fuel pump, to the HPP via the fuel filter.For additional information, refer to: Fuel Tank and Lines (310-01C Fuel Tank and Lines - TDV6 2.7L Diesel, Description and Operation).

FUEL FILTER

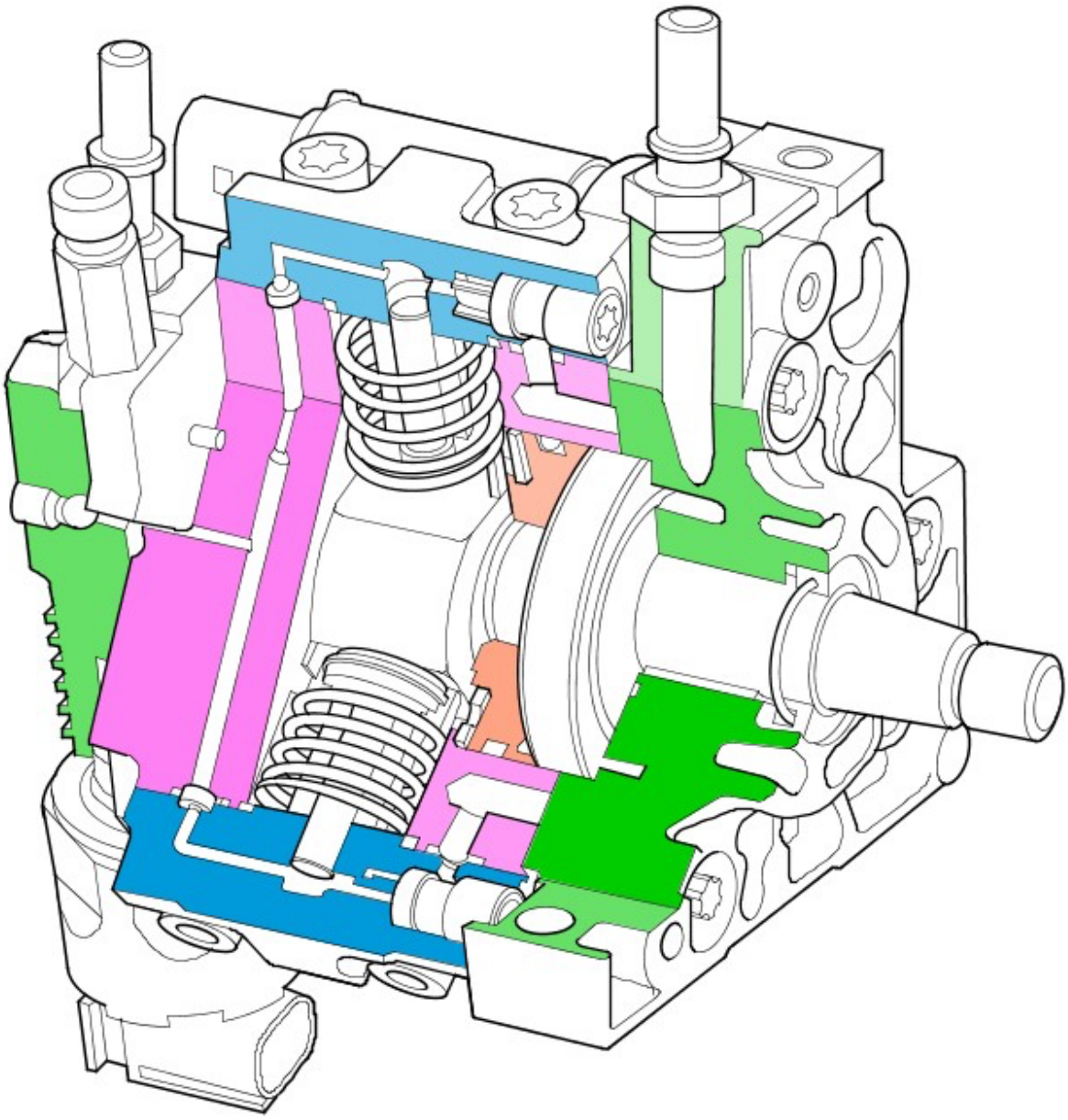
The fuel filter is located in the engine compartment on the left hand side, packaged to be protected against damage. Incorporated in the fuel filter housing is a bimetallic temperature valve, which will start to close at 30°C (86°F) and will fully close at 50°C (122°F). This allows pre-heated diesel fuel to circulate inside the fuel filter to prevent waxing in cold operating conditions.

FUEL COOLER

Two fuel coolers are fitted to the vehicle. One is located in the 'vee' of the engine block, and has a coolant system connection to aid heat transfer. The second cooler is located in the fuel return line and is a fuel to air cooler. For additional information, refer to: Fuel Tank and Lines (310-01C Fuel Tank and Lines - TDV6 2.7L Diesel, Description and Operation).

HP SYSTEM

HPP



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The HPP is a three-piston (120 degree apart) radial plunger pump with a HP displacement of 0.8 cc. As mentioned, it has the ability to produce a maximum pressure of 1650 bar. The housing is cast from iron, the flange is cast from aluminium.

The pump is driven from the camshaft via a toothed belt. It does not need to be timed to the engine during belt replacement in service.

The required supply pressure to the HPP is -0.3 bar to +0.5 bar gauge. The return pressure is -0.3 bar to +0.8 bar gauge.

The pump is sized to deliver sufficient fuel to the HP rails for all engine-operating conditions.

The HPP consists of the following components:

- Internal Transfer Pump (ITP)
- Volume Control Valve (VCV)
- HP pumping elements (3 of)
- Pressure Control Valve (PCV)

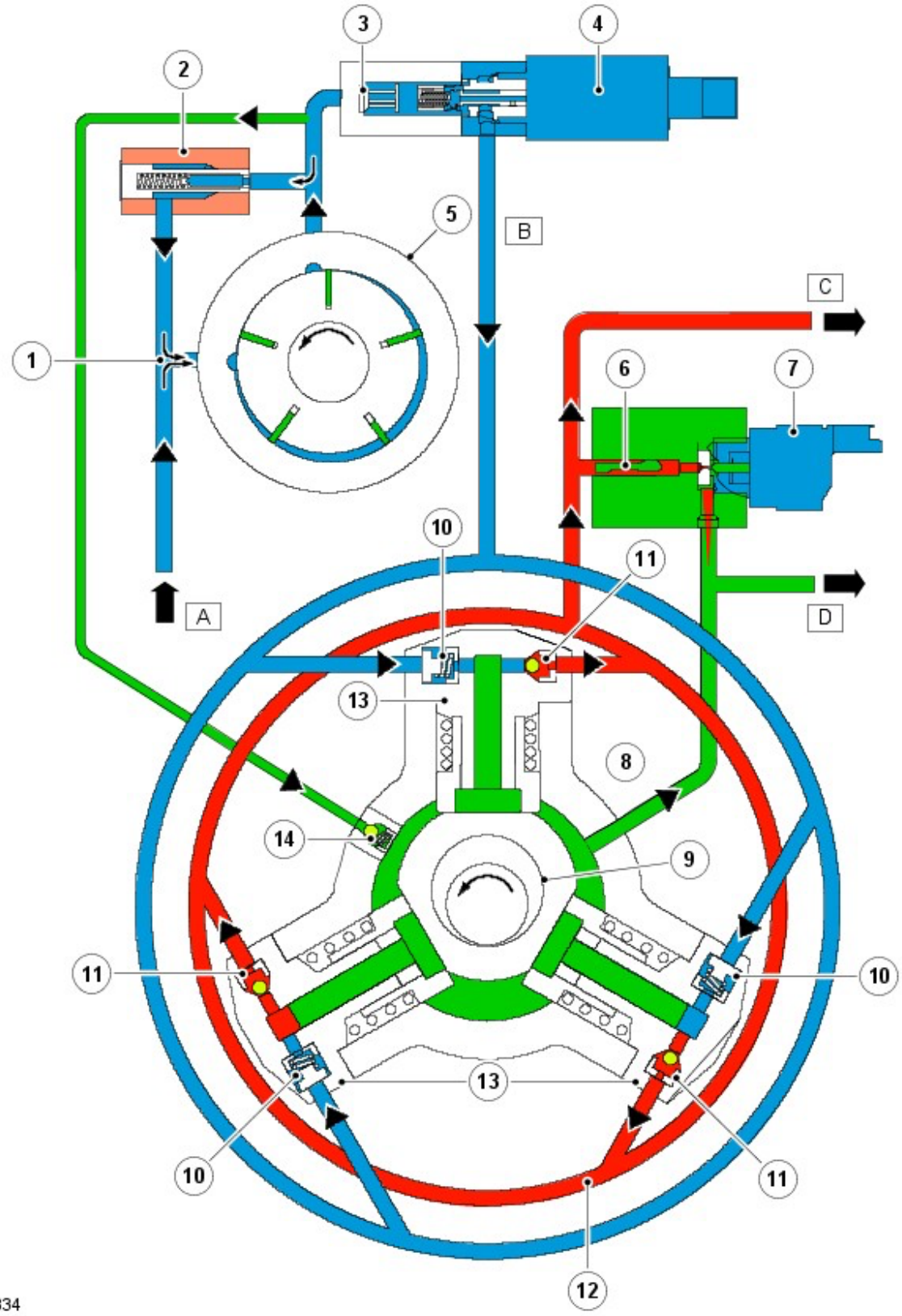
The ITP is a 5 vane pump. This conveys fuel to the VCV.

The VCV is a variable position solenoid valve electronically controlled by the ECM. The VCV is located between the ITP and the HP pumping elements. The VCV determines the amount of fuel that is delivered to the HP pumping elements. When there is no signal to the VCV the valve is closed, therefore no fuel delivery.

The 3 HP pumping elements are connected together in a fuel ring circuit within the pump. There is a single HP outlet connection for the HP pipe to the HP diverter rail.

The PCV is a variable position solenoid valve electronically controlled by the ECM. The PCV is located between the HP pumping elements and the HP outlet connection. The PCV regulates the amount of fuel pressure in the fuel rails and is controlled by the ECM. When there is no signal to the PCV the valve is open, therefore no rail pressure can be generated.

High Pressure Fuel Flow



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ITEM	DESCRIPTION
A	LP fuel supply
B	Fuel supply to the HP pumping elements
C	HP outlet connection to the HP diverter rail

D	LP fuel return (spill)
1	LP side of ITP
2	ITP pressure relief valve
3	Screen filter
4	VCV
5	ITP
6	Edge filter (to protect PCV)
7	PCV
8	N/A
9	Eccentric on HPP drive shaft
10	Pumping element inlet valve
11	Pumping element outlet valve
12	HP ring line
13	HPP elements (3 of)
14	Lubricating valve

The fuel induced by the ITP (5) is conveyed to the VCV (4) and the lubricating valve (14).

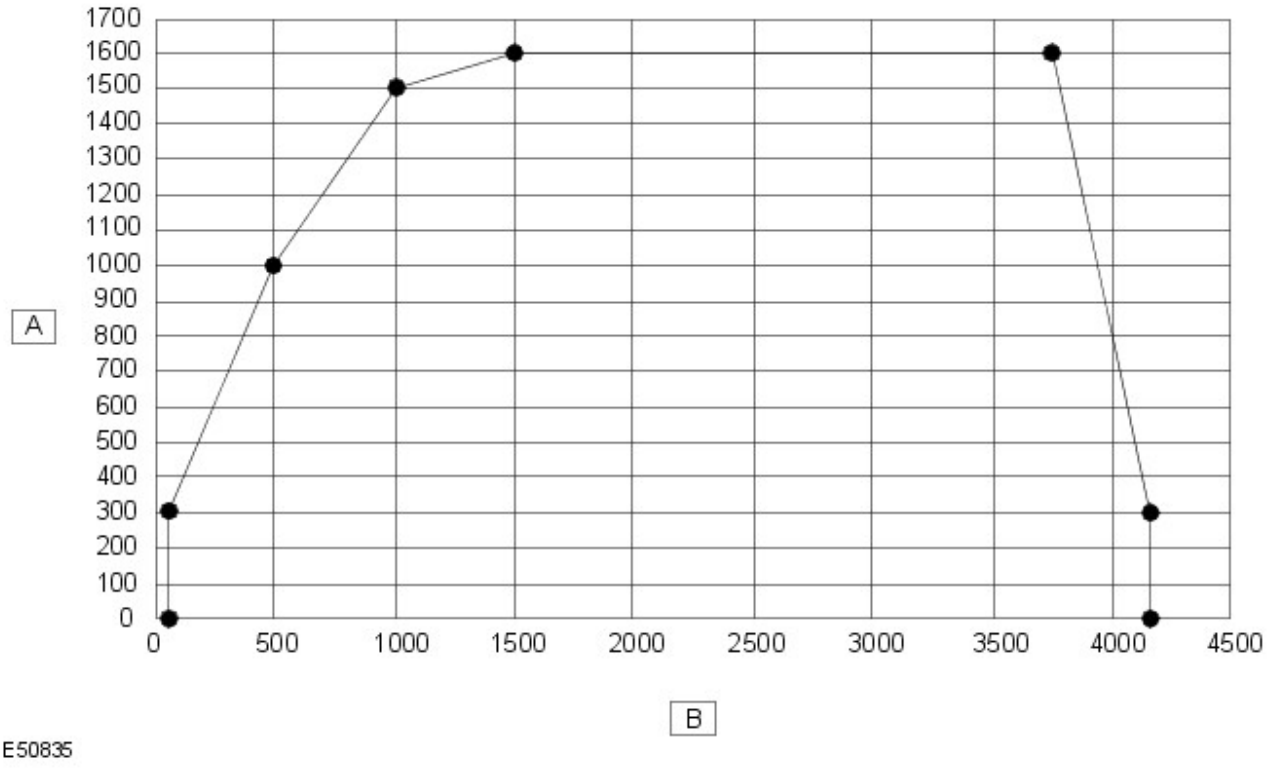
When the VCV is closed, the ITP pressure relief valve (2), lying parallel to the transfer pump, opens and conveys the fuel back to the LP side (1) of the transfer pump.

The fuel passes through the lubricating valve (14) into the interior of the HPP and from there to the fuel return (D). The fuel is used to lubricate the pump.

The VCV (4) determines the quantity of fuel (B) that is supplied to the pumping elements (13).

The fuel from the HP outlets (11) of the three pumping elements comes together in a ring line (12) and is conveyed through the HP outlet of the HPP ©) to the rails.

The PCV (7) regulates the fuel pressure in the fuel rails. Reducing rail pressure via the PCV results in fuel from the rail returning to the LP fuel return (D).



ITEM	DESCRIPTION
A	Pump pressure (bar)
B	Pump speed (rpm)

The HPP can supply up to 1600 bar fuel pressure continuously with short excursions to 1650 bar. Pump speed is 5/6 engine speed. However it is calibrated to deliver fuel pressure dependant upon engine speed and load and is always under full control.

When the HPP is rotated, pressure is created when the VCV is open and the PCV is closed. The VCV and PCV are variable position to allow variable fuel delivery and pressure control.

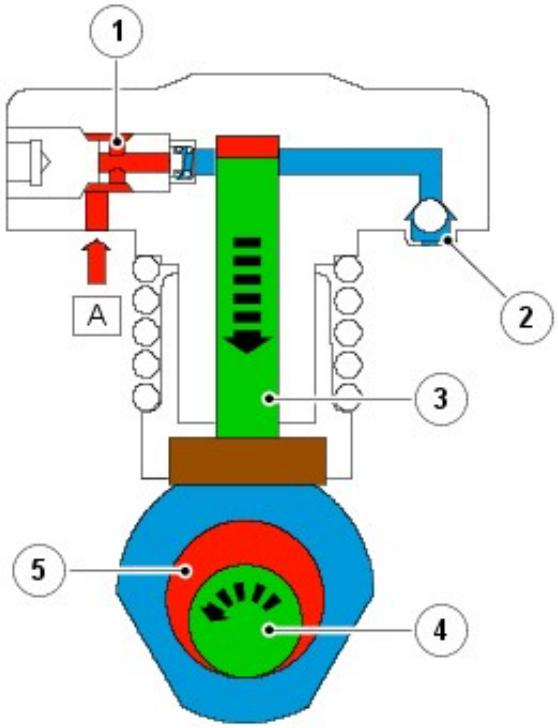
When the ECM actuates the piezo actuators, the rail pressure drop is off-set by additional fuel being delivered to the HP rails by the PCV.

Pressure Reduction After Engine Has Stopped

The fuel pressure in the system is reduced within a few seconds after the engine has stopped as the PCV no longer has the holding current it requires, and therefore opens. No residual pressure remains in the system and the fuel is returned to the fuel return line (D) through the open PCV. The system is pressureless.

Function of High A Pressure Element

Fuel Induction



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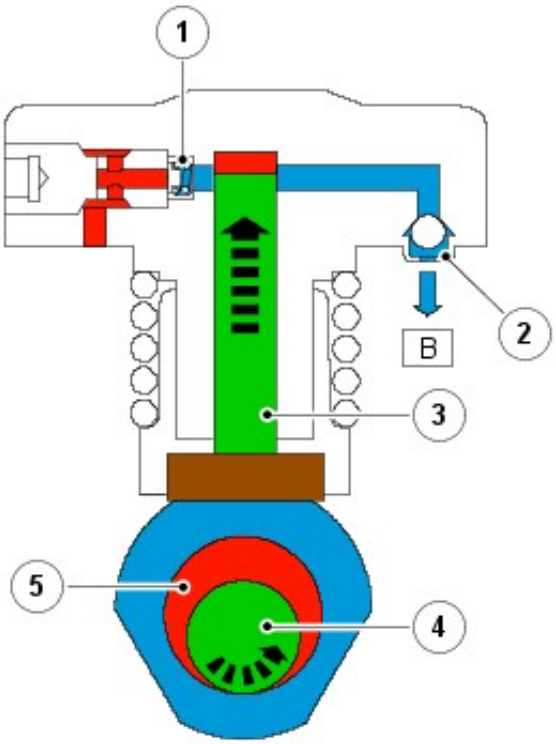
During the downward motion of the piston (3), a vacuum in the pump cylinder is generated, which opens the inlet valve (1) against the force exerted by the valve spring. The fuel (A), which is flowing past the VCV, is sucked in. At the same time the outlet valve (2) is closed due to the pressure difference between the pump cylinder and the HP fuel in the ring line.

Fuel Delivery



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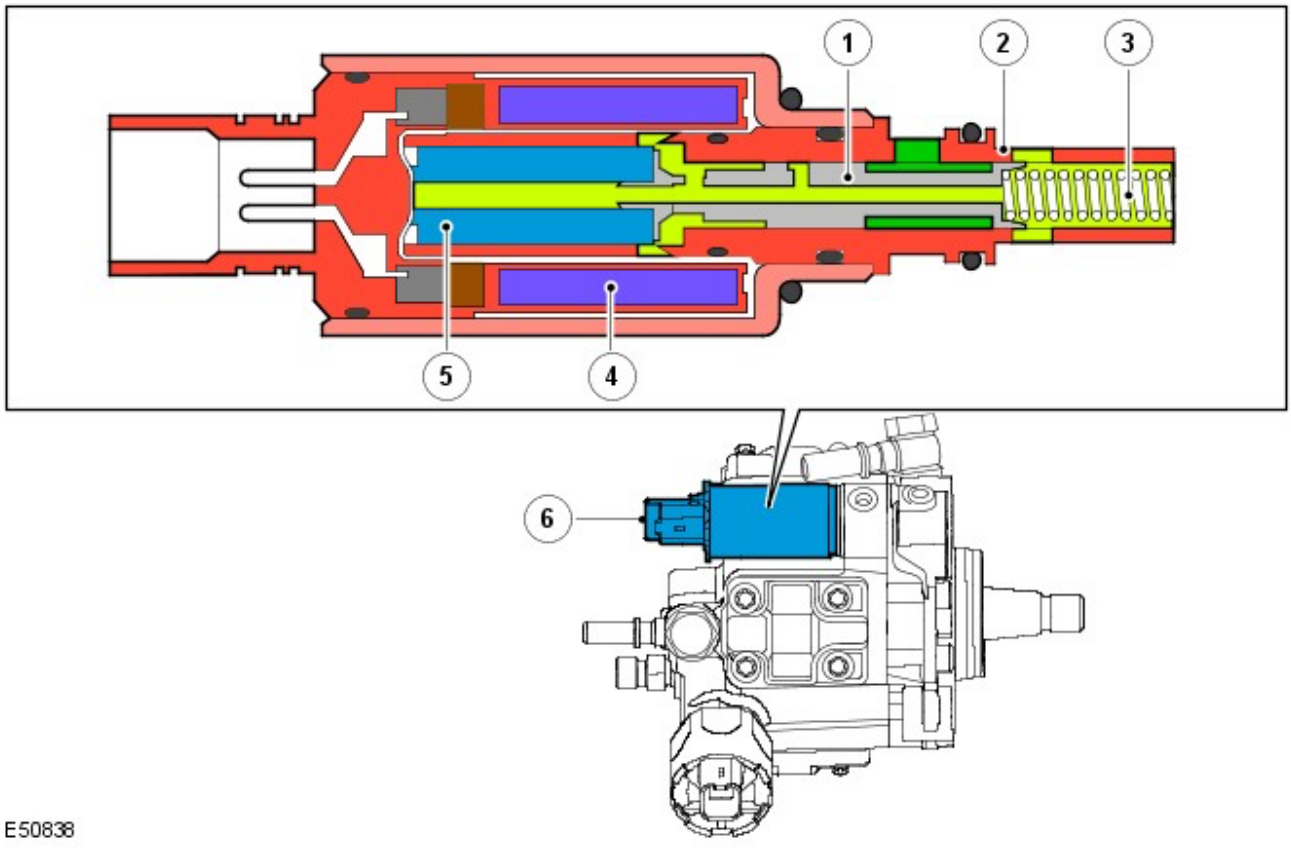
The eccentric on the HPP driveshaft (5) presses the piston (3) upwards. The inlet valve (1) is then closed through the force exerted by the valve spring and the pressure being built up in the pump cylinder. The outlet valve (2) opens when the pressure in the pump cylinder is greater than the fuel pressure in the ring line (B).

VOLUME CONTROL VALVE (VCV)



ITEM	DESCRIPTION
1	Piston
2	Sleeve
3	Compression spring
4	Coil
5	Armature
6	VCV

The VCV is fixed directly to the HPP.

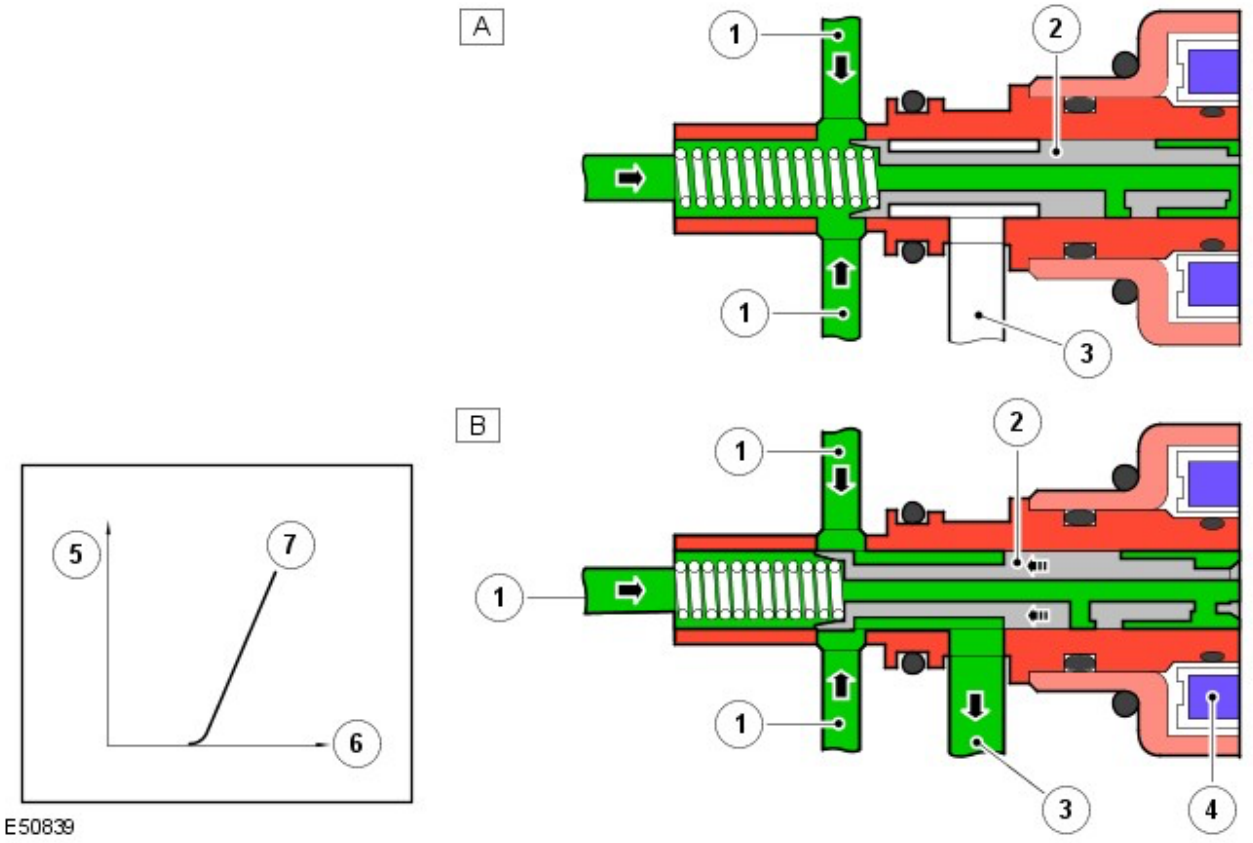
The VCV regulates the fuel supply (and hence the quantity of fuel) from the transfer pump to the HPP elements, depending on the fuel pressure in the rail.

This makes it possible to match the delivery of the HPP to the requirements of the engine from the low-pressure side. The quantity of fuel flowing back to the main fuel supply line is kept to a minimum.

In addition, this adjustment reduces the power consumption of the HPP, improving the efficiency of the engine.

NOTES:

- The fuel volume control valve default is closed without electrical supply. An open circuit connector will prevent the engine from running.
- The VCV cannot be replaced as a separate component in service.



ITEM	DESCRIPTION
A	VCV not actuated
B	VCV actuated
1	Fuel supply from the transfer pump
2	Piston
3	Fuel supply to the HPP
4	Coil energised
5	Quantity of fuel
6	Control current
7	VCV at constant engine speed

VCV Not Actuated (A)

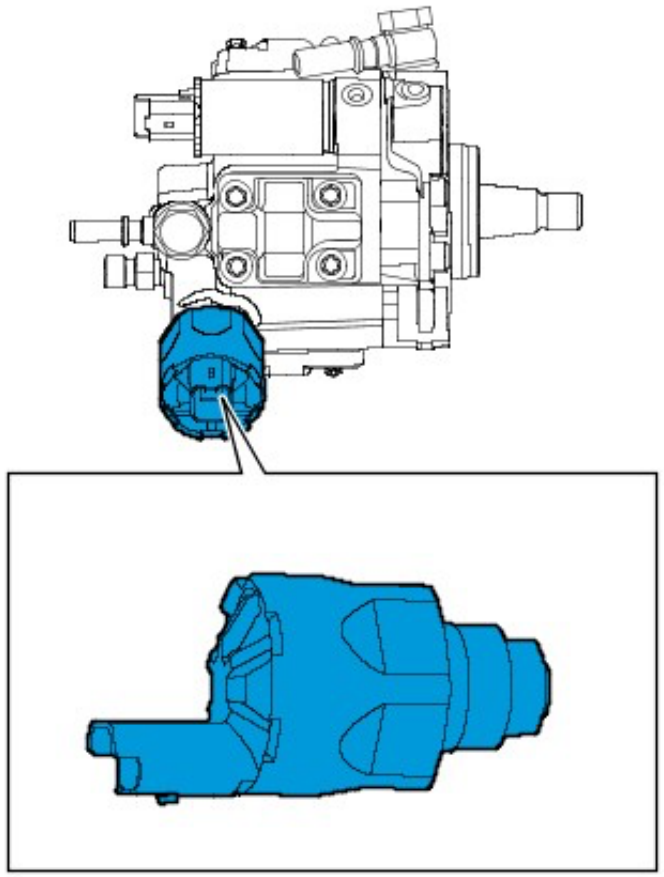
When there is no power supplied, the piston (2) closes the opening between the two connections (1) and (3) through the force of the compression spring. The fuel supply to the HPP is interrupted.

VCV Actuated (B)

The ECM energizes the coil (4) of the valve, according to the engines requirements. The armature force is proportional to the control current and counteracts the compression spring through the moving piston (2).

As a result, the opening between the two connections (1) and (3) and hence the quantity of fuel (5) supplied through the connector (3) to the HPP is also proportional to the control current (6). This means that the greater the opening cross-section, the greater the quantity of fuel supplied.

PRESSURE CONTROL VALVE (PCV)



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The PCV is located on the HPP. It governs the fuel pressure at the HP outlet of the HPP and thus, the fuel pressure within the rail. In addition, the PCV dampens the fluctuations in the pressure, which occur during the delivery of fuel through the HPP and through the injection process.

The PCV ensures that optimum pressure exists in the rail for every operating condition of the engine.

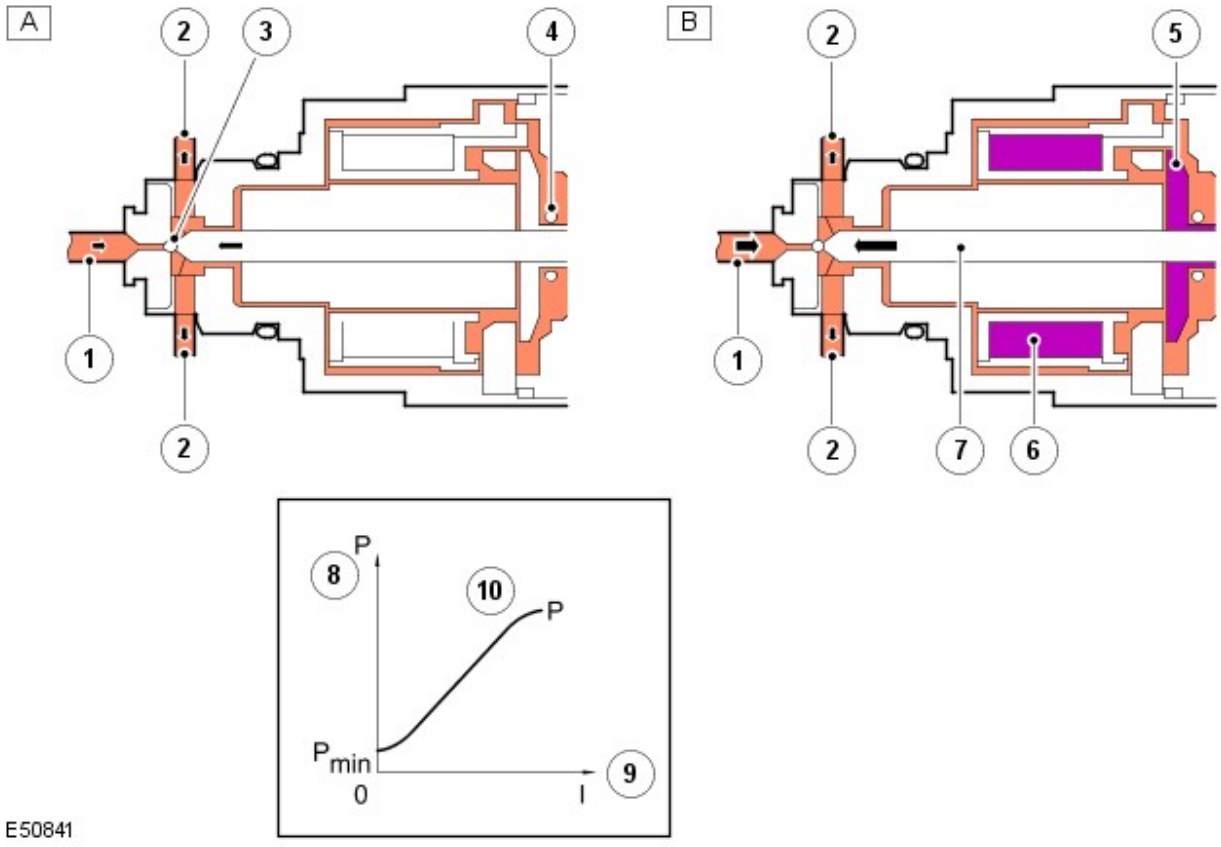
The PCV is an electro-magnetically operated valve with spring support.

The electrical current supplied by the ECM through the solenoid pulls back the control pin. This allows the

diesel fuel to pass the ball valve and thus the fuel flow into the common rails.

The entire armature is coated with fuel for lubrication and cooling.

> **NOTE:**
>
> The PCV cannot be replaced as a separate component in service.



ITEM	DESCRIPTION
A	PCV non-controlled
B	PCV controlled
1	Fuel from the HPP
2	To fuel return
3	Ball valve
4	Compression spring
5	Armature
6	Coil energised
7	Control pin
8	High pressure fuel

9	Control current
10	Characteristic of the PCV

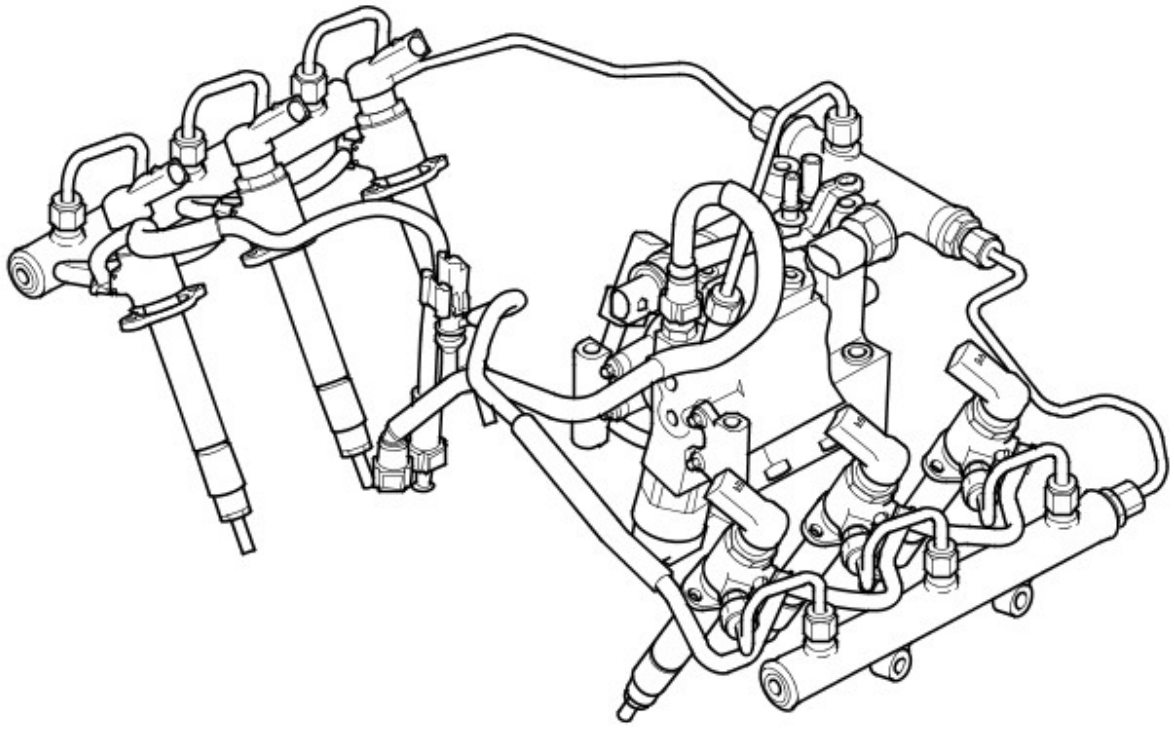
PCV Non-controlled (A)

The ball valve (3) will only be operated through the force exerted upon it by the spring (4). Thereby, the PCV is classed as open.

PCV Controlled (B)

The current flowing through the solenoid (6) draws the pin (7) down. This in turn transfers the magnetic force via the pin to the ball valve (3). The pull of the pin, and the pressure on the ball valve, is proportional to the valve flow (9).

HP COMMON FUEL RAILS



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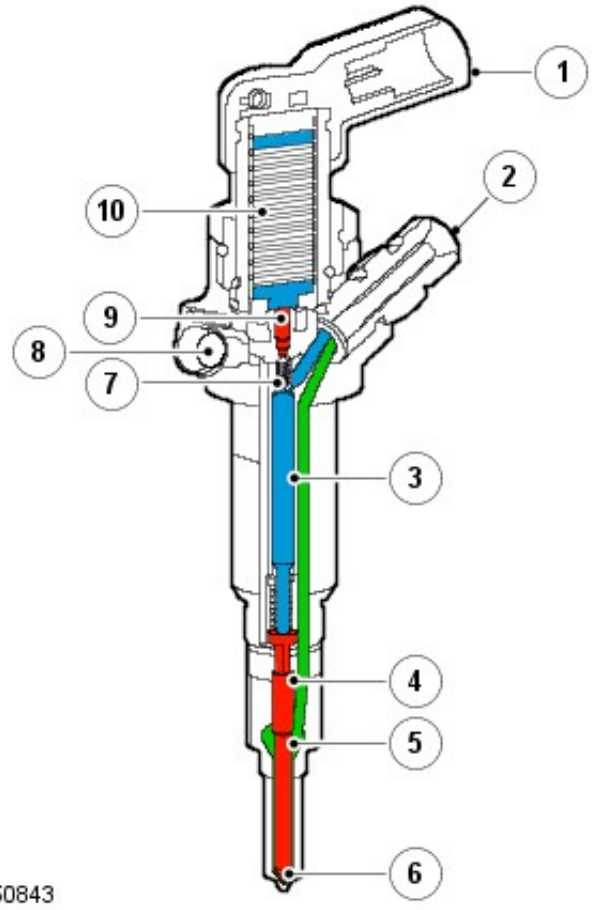
The fuel rails are manufactured from forged steel. They store the fuel at high pressure and prevent pressure fluctuations in the HP system.

All HP pipes have an internal diameter of 2.5mm except the pipes to the injectors, which are 3.0mm. Total rail volume is 33cc.



ITEM	DESCRIPTION
1	Harness connection
2	HP connection
3	Control piston
4	Nozzle needle
5	Nozzle HP chamber
6	Nozzle spray holes
7	Valve mushroom
8	Fuel return
9	Valve piston
10	Piezo actuator

The fuel injectors are operated directly by the ECM for fuel metering (start of injection and quantity of fuel

injected).

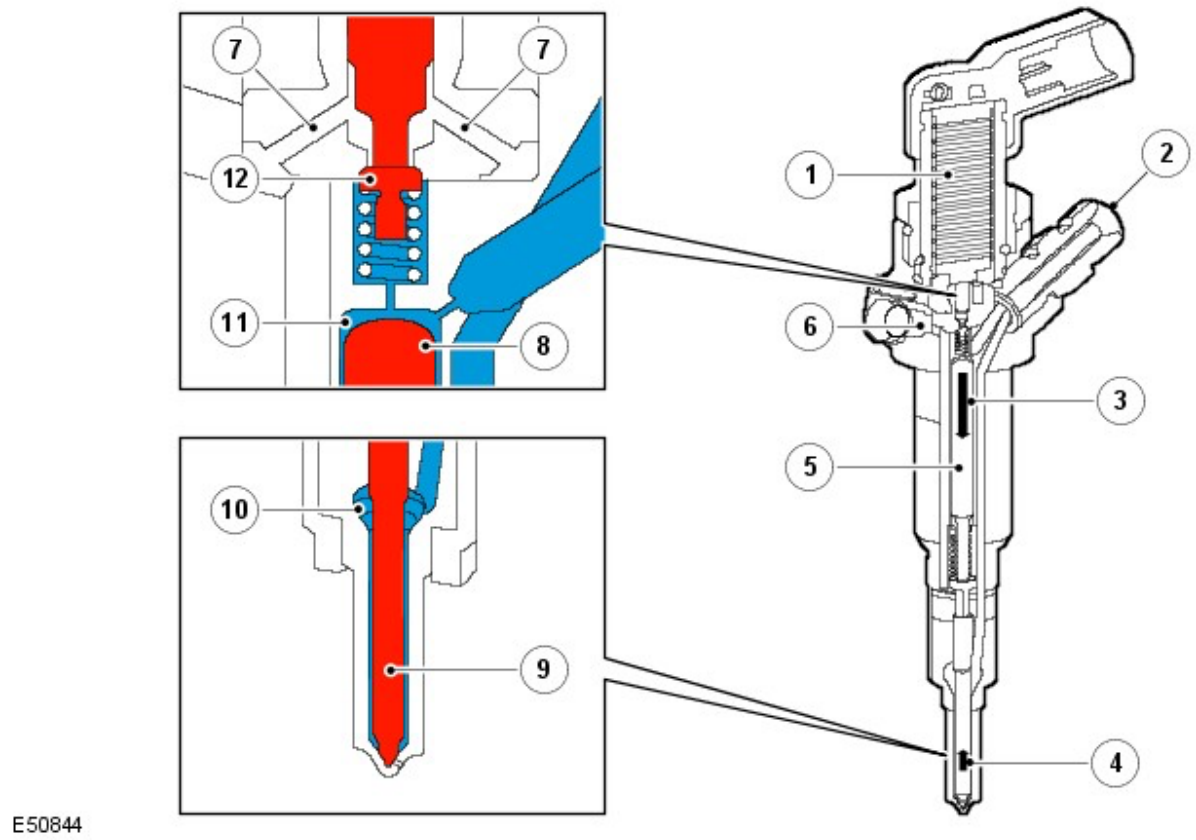
The operating components of the piezo fuel injectors are:

- The piezo actuator
- The injector body containing the hydraulic servo system
- The fuel injector nozzle

NOTES:

- New injectors can be installed in any cylinder and DO NOT have to be configured.
- Each Injection event is controlled by a charge and discharge cycle allowing energy to dissipate in, and recover from, the injector. Never disconnect the wiring connector when the vehicle is running. The injector may remain open thus causing engine damage.
- For safety reasons, the engine must be at standstill for 30 seconds before starting work on the HP fuel systems.

FUEL INJECTOR NOT ACTUATED (NOT INJECTING FUEL)



ITEM	DESCRIPTION
1	Piezo actuator
2	HP connection

3	Hydraulic force applied on control piston
4	Hydraulic force acting on tip of nozzle
5	Control piston
6	Fuel return
7	Fuel return
8	Control piston
9	Nozzle needle
10	High pressure chamber of nozzle
11	Control chamber
12	Valve mushroom

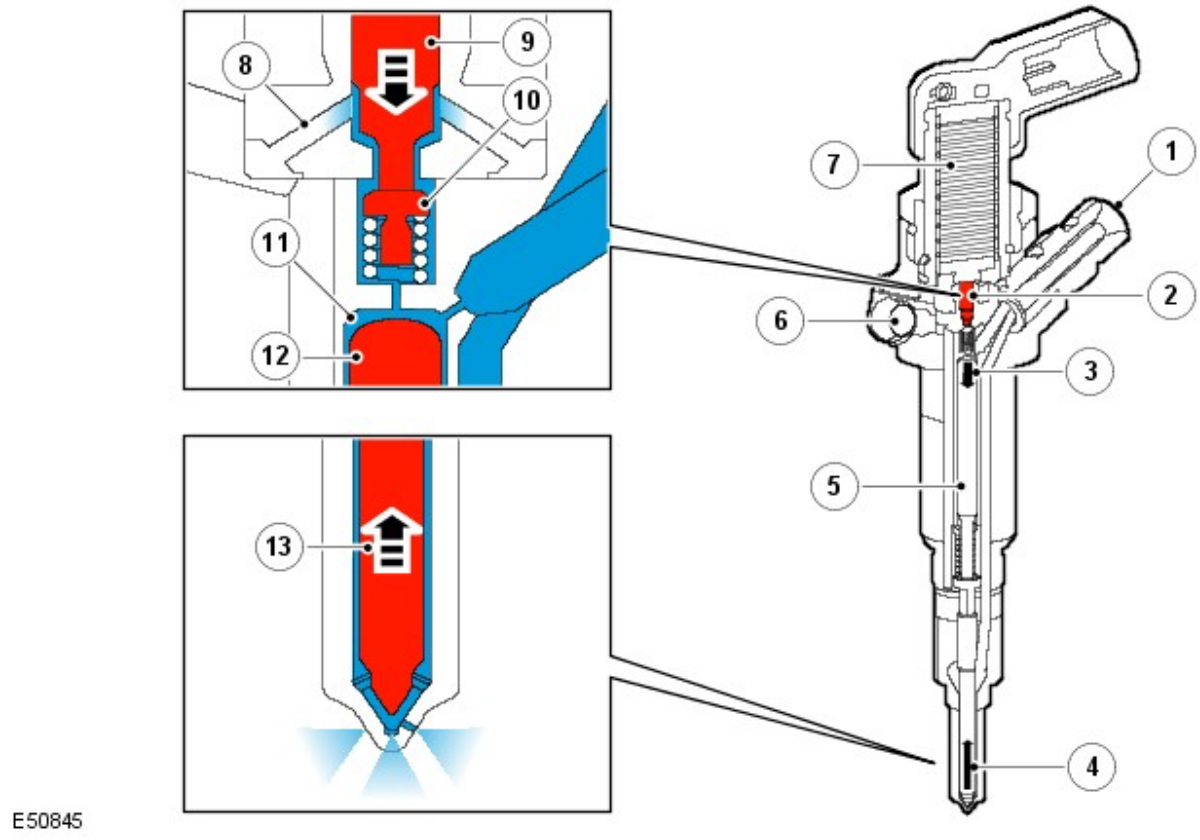
The HP fuel from the fuel-rail passes through the HP connection (2) into the control chamber (11) and into the HP chamber (10) of the fuel injector nozzle.

The piezo actuator (1) is currentless and the valve mushroom (12) closes the bore to the fuel return (7) by means of spring pressure.

There is how ever a continuous fuel return (6) to vent internal leakage within the injector.

The hydraulic force (3), which is now applied on the control piston by the fuel under high pressure in the control chamber (11) through the control piston (8), is greater than the hydraulic force (4) acting on the tip of the nozzle (since the area of the control piston in the control chamber is greater than the area of the tip of the nozzle).

FUEL INJECTOR ACTUATED (INJECTING FUEL)



ITEM	DESCRIPTION
1	High pressure supply
2	Valve piston
3	Hydraulic force applied on control piston
4	Hydraulic force acting on tip of nozzle
5	Control piston
6	Fuel return
7	Piezo actuator
8	Fuel return
9	Valve piston
10	Valve mushroom
11	Control chamber
12	Control piston
13	Nozzle needle

The piezo actuator (7) energized by the ECM extends (charging phase) and presses on the valve piston (9).

The valve mushroom (10) opens the bore, which connects the control chamber (11) to the fuel return (8 then 6).

As a result, the pressure in the control chamber drops, and the hydraulic force (4) acting on the tip of the nozzle needle is now greater than the force (3) acting on the control piston in the control chamber.

The nozzle needle (13) moves upwards and the fuel passes through the six spray holes into the combustion chamber.

ENGINE STARTING

During starting, the fuel rail pressure must be at least 150 bar. Should the pressure be below this figure, the injectors will not operate, resulting in the vehicle not starting.

ENGINE STOPPED

To stop the engine the ECM stops energising the piezo actuators, therefore, no fuel is injected and the engine speed drops to zero.

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