Service.

Self-Study Programme 209

1.9-ltr. TDI Engine with Pump Injection System

Design and Function

Something new has happened to the diesel engine

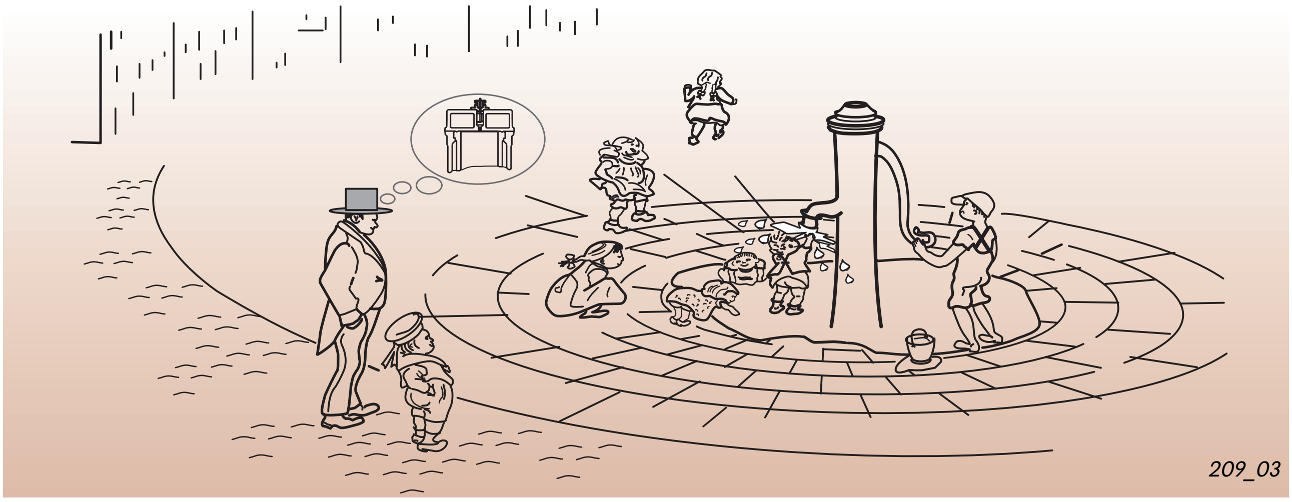
The demands on the modern diesel engine with regard to performance, fuel economy, exhaust emissions and noise levels are growing constantly.
Good mixture preparation is a key factor for meeting these requirements.
This calls for efficient injection systems which produce high injection pressures to ensure that fuel is atomised very finely. Also, it is necessary to precisely control the commencement of fuel injection and injection quantity.

The pump injection system meets these tough requirements.

Even Rudolf Diesel thought about combining the injection pump and injector in one unit in order to dispense with high-pressure lines and thereby achieve high injection pressures. However, he did not have the technical means to put this idea into practice.

This is how it might have looked:

In 1905, Rudolf Diesel came up with the idea of a pump injector.



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Diesel engines with mechanically controlled pump injection systems have been in use in ships and trucks since the 1950s.
For the first time, Volkswagen, in association with Robert Bosch AG, has succeeded in developing a diesel engine with a solenoid valve controlled pump injection system suitable for use in passenger cars.

A step into the future, this engine meets the tough demands on performance and clean emissions. At this rate, Rudolf Diesel's vision of "smoke- and odour-free exhaust gases“ will one day become reality.

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Introduction

1.9-ltr. TDI engine with pump injection system


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It was developed on the basis of the 1.9-ltr./ 81kW TDI engine with no intermediate shaft. Only through the injection system does it differ from the engine fitted with a distributor injection pump.

On the following pages we will explain everything about the design and the mode of functioning of the pump injection system and we will show you the necessary modifications to the fuel system, engine management system and engine mechanicals.

The diesel engine with the pump injection system has the following advantages over the distributor injection pump:

- Low combustion noise
- Clean emissions
- Low fuel consumption
- High efficiency

These advantages are attributable to:

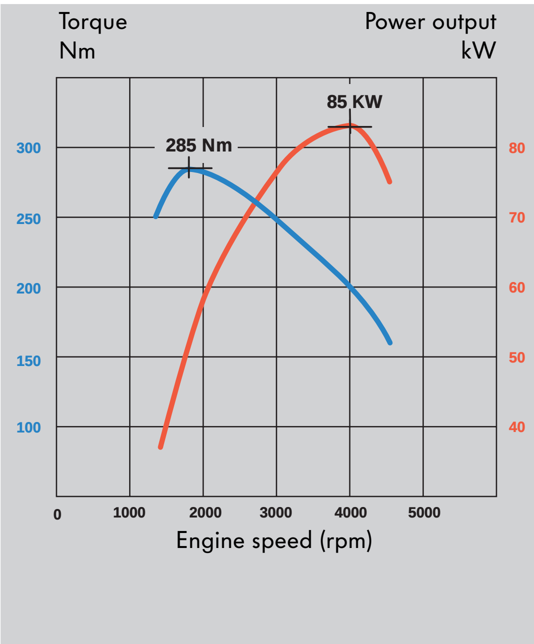
- The high injection pressures of up to 2050 bar
- Precise control of the injection cycle
- The pre-injection cycle

Specifications

Engine code:	AJM
Type:	4-cylinder in-line engine
Stroke/bore:	79.5mm/ 95.5mm
Compression ratio:	18 : 1
Mixture preparation Engine management:	Electronic Diesel Control, Bosch EDC 15 P
Fuel type:	Diesel, at least 49CN, or biodiesel (RME)
Exhaust gas aftertreatment:	Exhaust gas recirculation and oxidation catalytic converter

The engine conforms to exhaust emission level D3.

Output and torque curve



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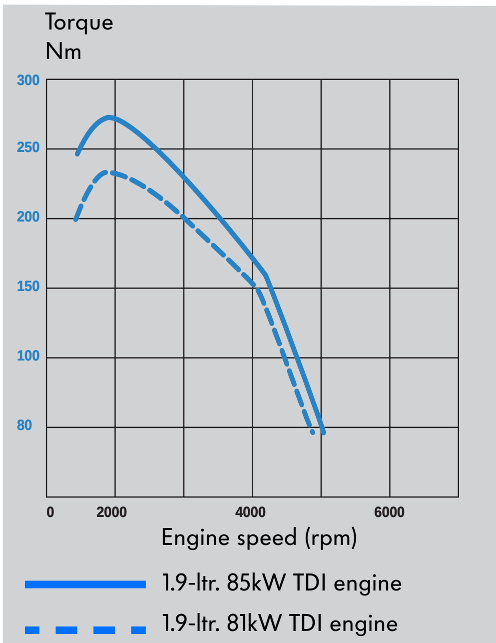
Thanks to the high injection pressures up to 2050 bar and the favourable effect they have on the combustion process, the engine develops 285Nm of torque at only 1900rpm.
Maximum power output is 85kW at 4000rpm.

Comparative torque curve



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From the same displacement, the engine with pump injection system develops 21% more torque than the 1.9-ltr. 81kW TDI engine with distributor injection pump.

Pump injection system

General information

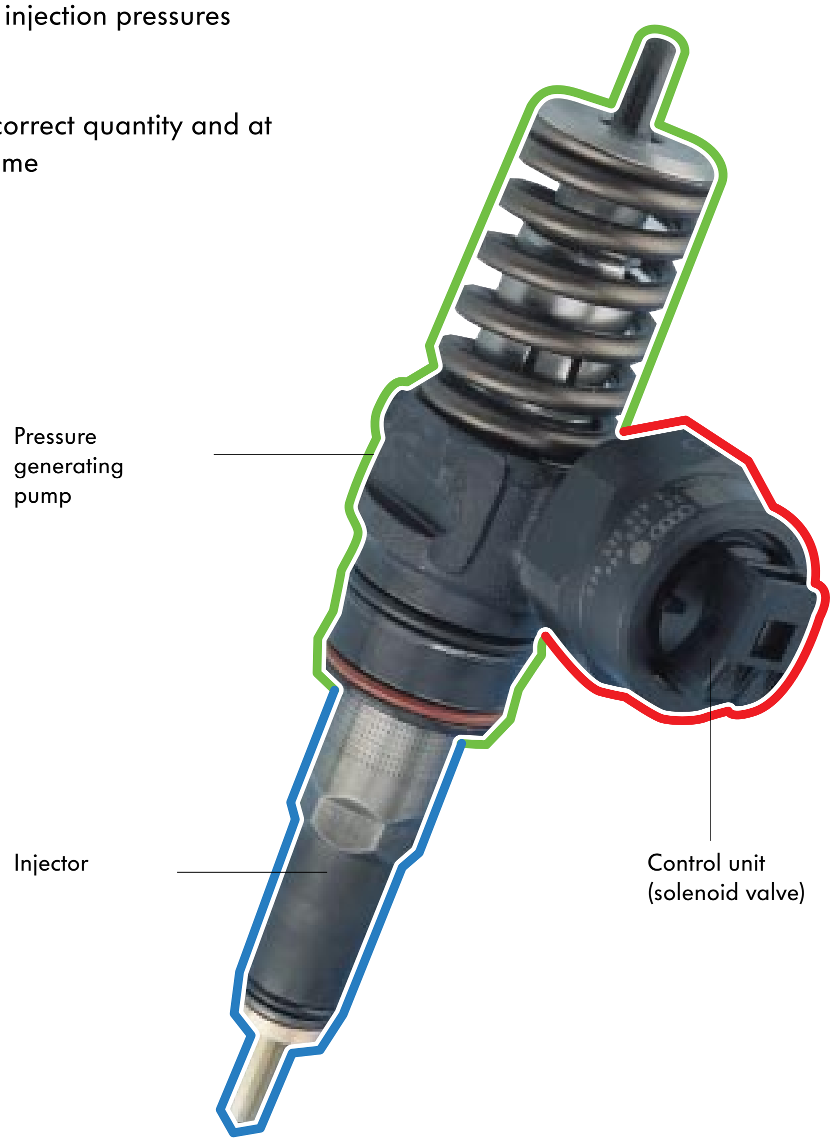
What is a pump injector?

A pump injector is, as the name already implies, an injection pump combined with a control unit and an injector.

Each cylinder of the engine has a pump injector. This means that there is no longer any need for a high-pressure line or a distributor injection pump.

Just like a distributor injection pump with injectors, the pump injection system has the following tasks:

- Generating the high injection pressures required
- Injecting fuel in the correct quantity and at the correct point in time



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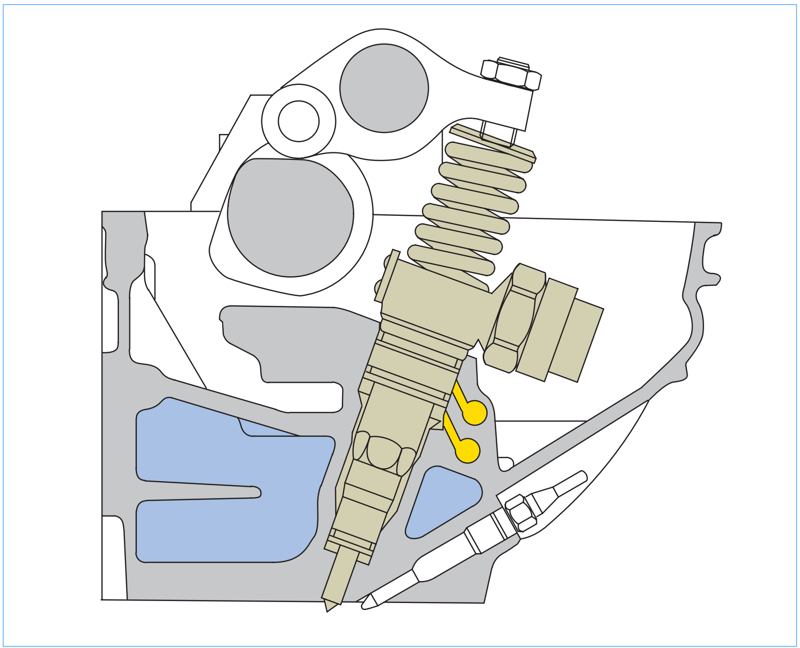
Fitting location



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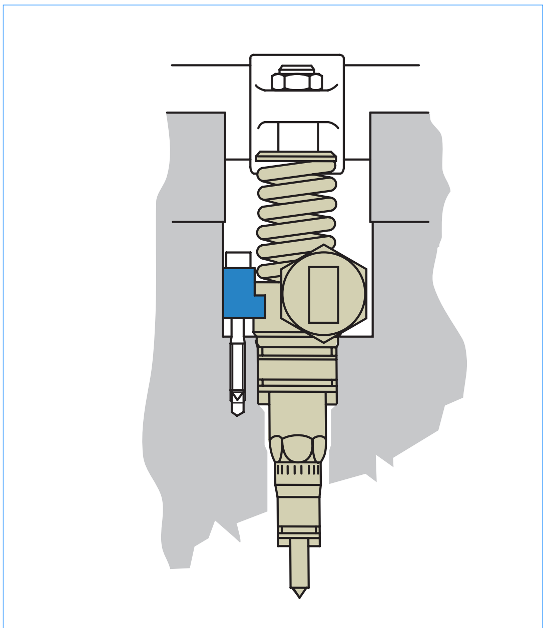
The pump injector is directly integrated in the cylinder head.

Fixing



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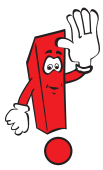
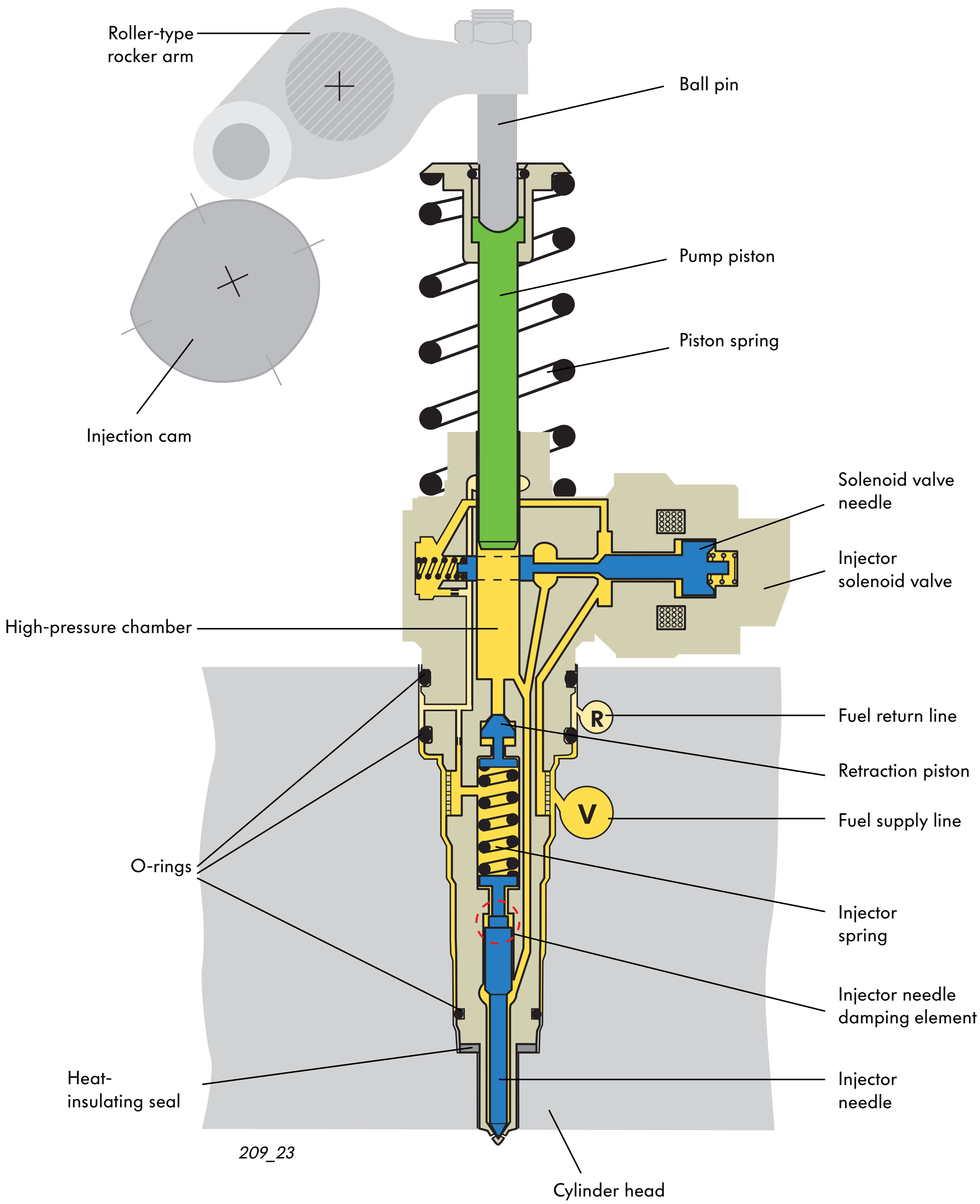
It is attached to the cylinder head by a clamping block.



It is important to ensure that the pump injector is installed in the correct position.
If the pump injector is not perpendicular to the cylinder head, the fastening bolt can come undone. The pump injector and/or the cylinder head may be damaged as a result. Please observe the instructions given in the Workshop Manual.

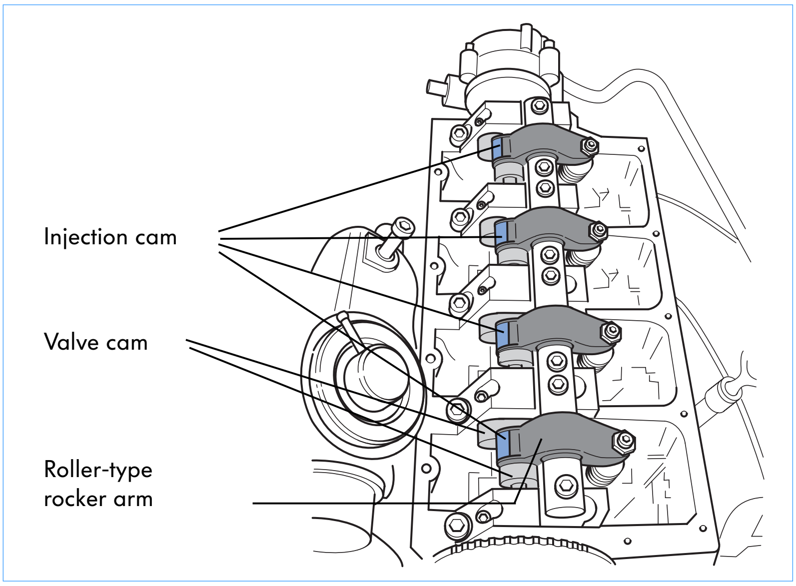
Pump injection system

Design



Drive mechanism

The camshaft has four additional cams for driving the pump injector. They activate the pump pistons of the pump injector via roller-type rocker arms.



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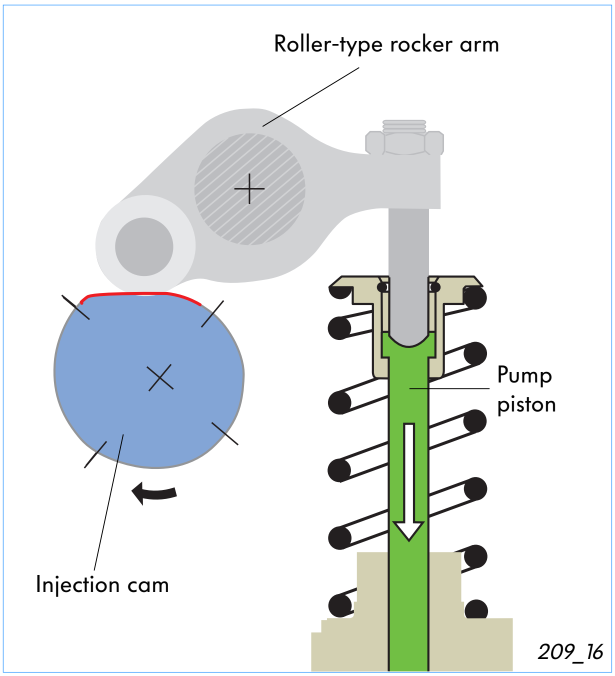
The injection cam has a **steep leading edge. . .**

As a result, the pump piston is pushed down at high velocity and a high injection pressure is attained quickly.

. . . and a flat trailing edge.

As a result, the pump piston moves up and down slowly and evenly, allowing fuel to flow free of air bubbles into the high-pressure chamber of the pump injector.



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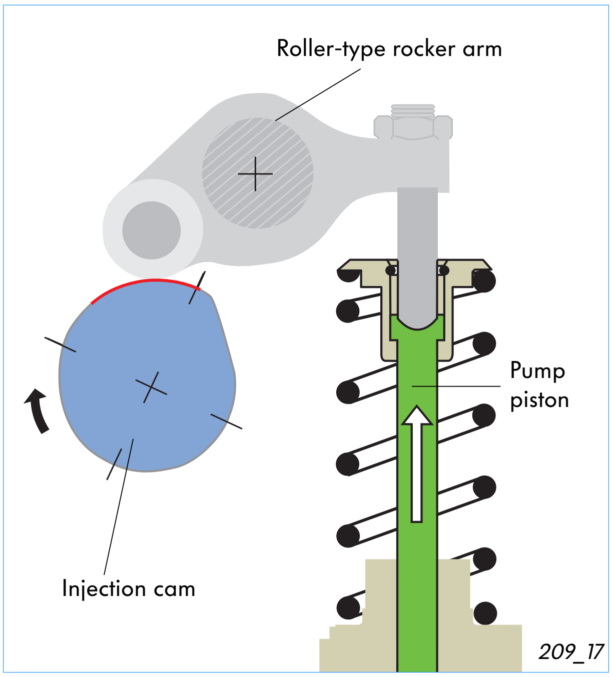

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Pump injection system

Requirements relating to mixture formation and combustion

Good mixture formation is a vital factor to ensure efficient combustion.
Accordingly, fuel must be injected in the correct quantity at the right time and at high pressure. Even minimal deviations can lead to higher levels of pollutant emission, noisy combustion or high fuel consumption.

A short firing delay is important for the combustion sequence of a diesel engine. The firing delay is the period between the start of fuel injection and the start of pressure rise in the combustion chamber. If a large fuel quantity is injected during this period, the pressure will rise suddenly and cause loud combustion noise.

Pre-injection cycle

To ensure the combustion process is as soft as possible, a small amount of fuel is injected at a low pressure before the start of the main injection cycle. This injection process is known as the pre-injection cycle. Combustion of this small quantity of fuel causes the pressure and temperature in the combustion chamber to rise.

This meets the requirements for quick ignition of the main injection quantity, thus reducing the firing delay. The pre-injection cycle and the "injection interval" between the pre-injection cycle and the main injection cycle produce a gradual rise in pressure within the combustion chamber, not a sudden pressure build-up. The effects of this are low combustion noise levels and lower nitrogen oxide emission.

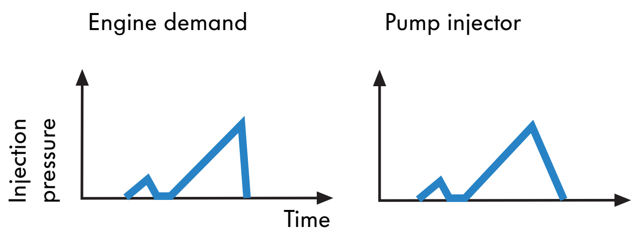
Main injection cycle

The key requirement for the main injection cycle is the formation of a good mixture, the aim being to burn the fuel completely if possible. The high injection pressure finely atomises the fuel in such a way that the fuel and air can mix well with one another. Complete combustion reduces pollutant emission and ensures high engine efficiency.

End of injection

At the end of the injection process, it is important that the injection pressure drops quickly and the injector needle closes quickly. This prevents fuel at a low injection pressure and with a large droplet diameter from entering the combustion chamber. The fuel does not combust completely, giving rise to higher pollutant emissions.

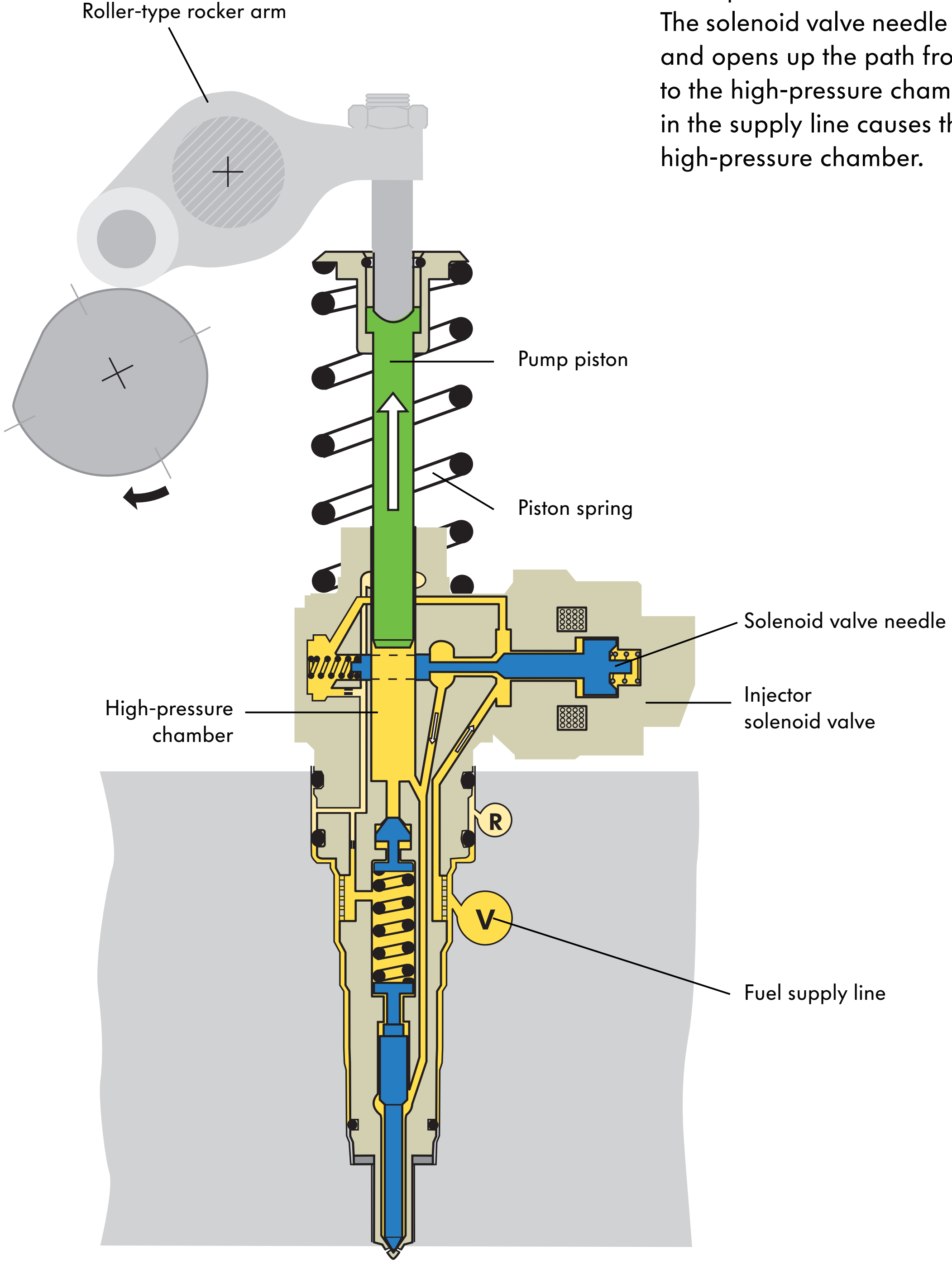
The injection curve of the pump injection system largely matches the engine's demands, with low pressures during the pre-injection cycle, followed by an "injection interval", then a rise pressure during the main injection cycle. The injection cycle ends abruptly.



The injection cycle

The high-pressure chamber is filled

During the filling cycle, the pump piston moves upwards under the force of the piston spring and thus increases the volume of the high-pressure chamber.
The injector solenoid valve is not activated.
The solenoid valve needle is in its resting position and opens up the path from the fuel supply line to the high-pressure chamber. The fuel pressure in the supply line causes the fuel to flow into the high-pressure chamber.



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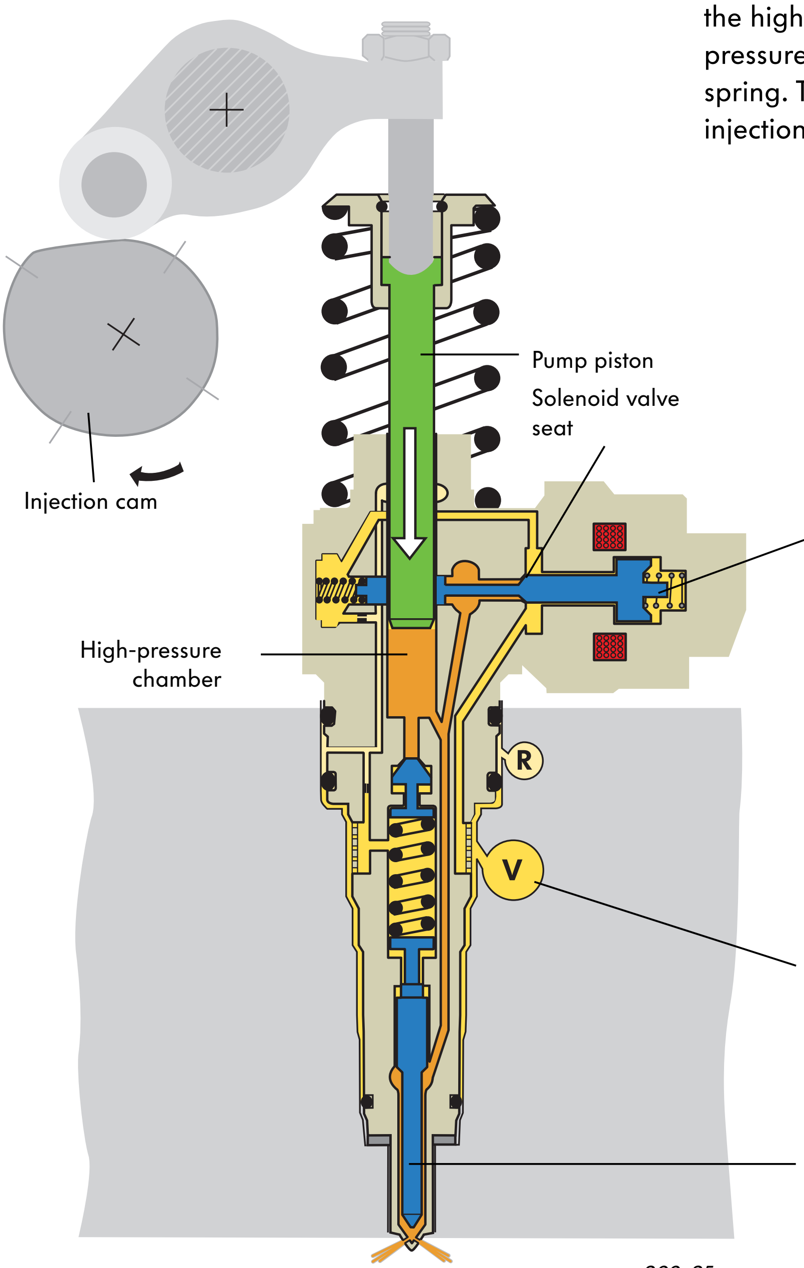
The injection cycle

The pre-injection cycle commences

The injection cam pushes the pump piston down via the roller-type rocker arm and thus displaces fuel out of the high-pressure chamber into the fuel supply line.
The engine control unit initiates the injection cycle by activating the injector solenoid valve. In the process, the solenoid valve needle is pressed down into the valve seat and closes off the path from the high-pressure chamber to the fuel supply line. This initiates a pressure build-up in the high-pressure chamber. At 180 bar, the pressure is greater than the force of the injector spring. The injector needle is lifted and the pre-injection cycle commences.



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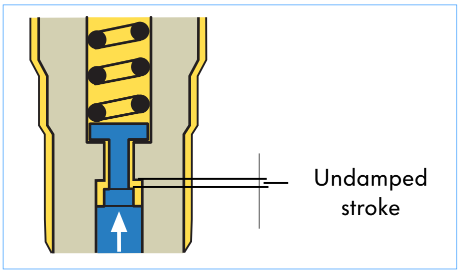
The pre-injection cycle commences

Injector needle damping

During the pre-injection cycle, the stroke of the injector needle is dampened by a hydraulic 'cushion'. As a result, it is possible to meter the injection quantity exactly.

This is how it works:

In the first third of the total stroke, the injector needle is opened undamped. The pre-injection quantity is injected into the combustion chamber.



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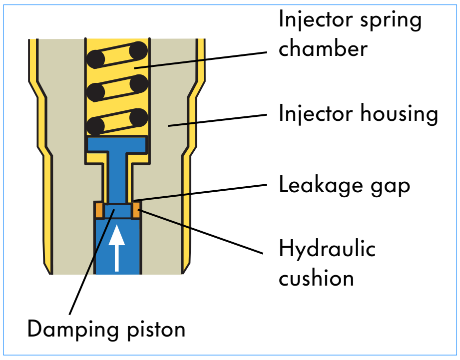
As soon as the damping piston plunges into the bore in the injector housing, the fuel above the injector needle can only be displaced into the injector spring chamber through a leakage gap. This creates a hydraulic 'cushion' which limits the injector needle stroke during the pre-injection cycle.



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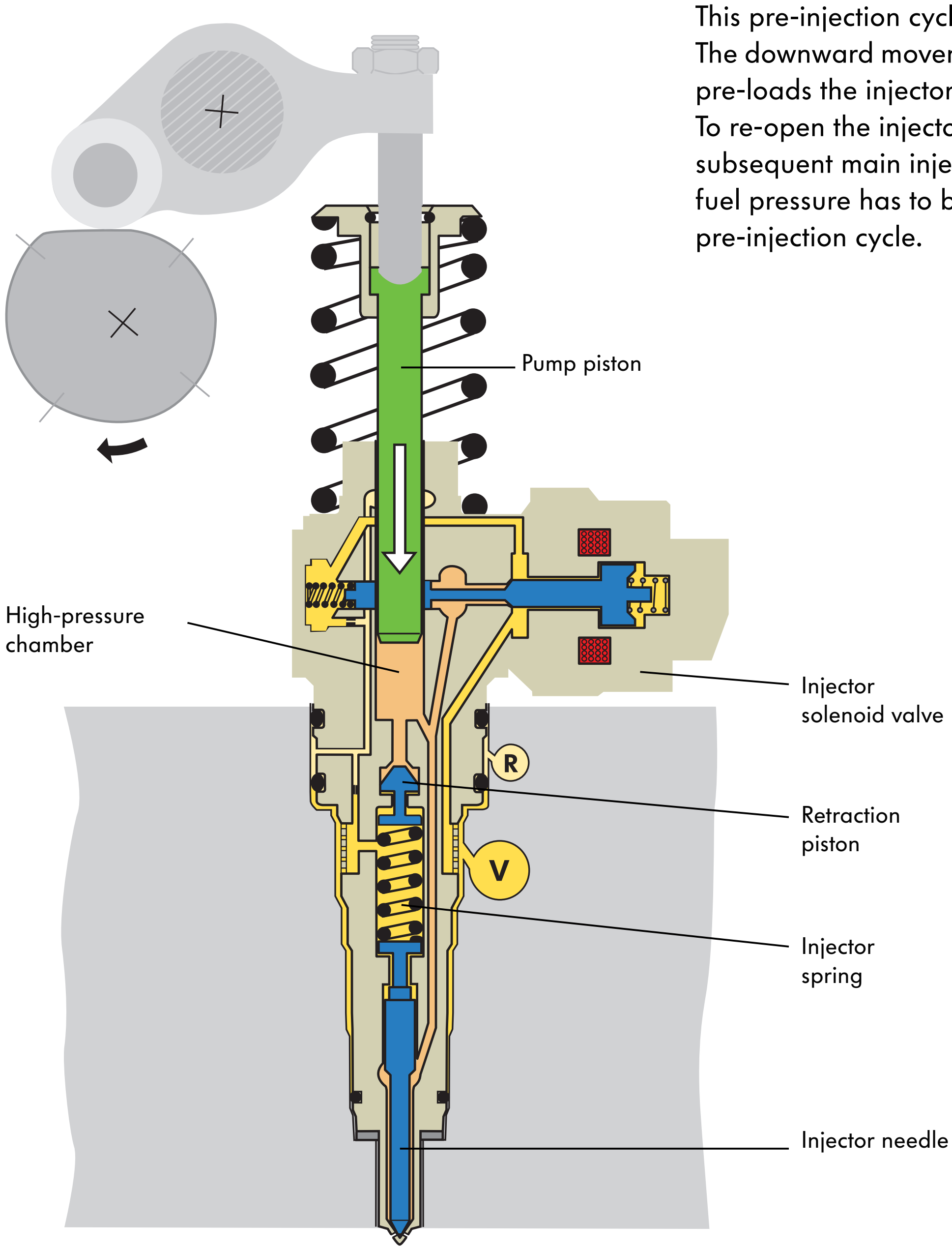
The injection cycle

End of pre-injection cycle

The pre-injection cycle ends straight after the injector needle opens. The rising pressure causes the retraction piston to move downwards, thus increasing the volume of the high-pressure chamber.
The pressure drops momentarily as a result, and the injector needle closes.
This pre-injection cycle now ends.
The downward movement of the retraction piston pre-loads the injector spring to a greater extent.
To re-open the injector needle during the subsequent main injection cycle, therefore, the fuel pressure has to be higher than during the pre-injection cycle.



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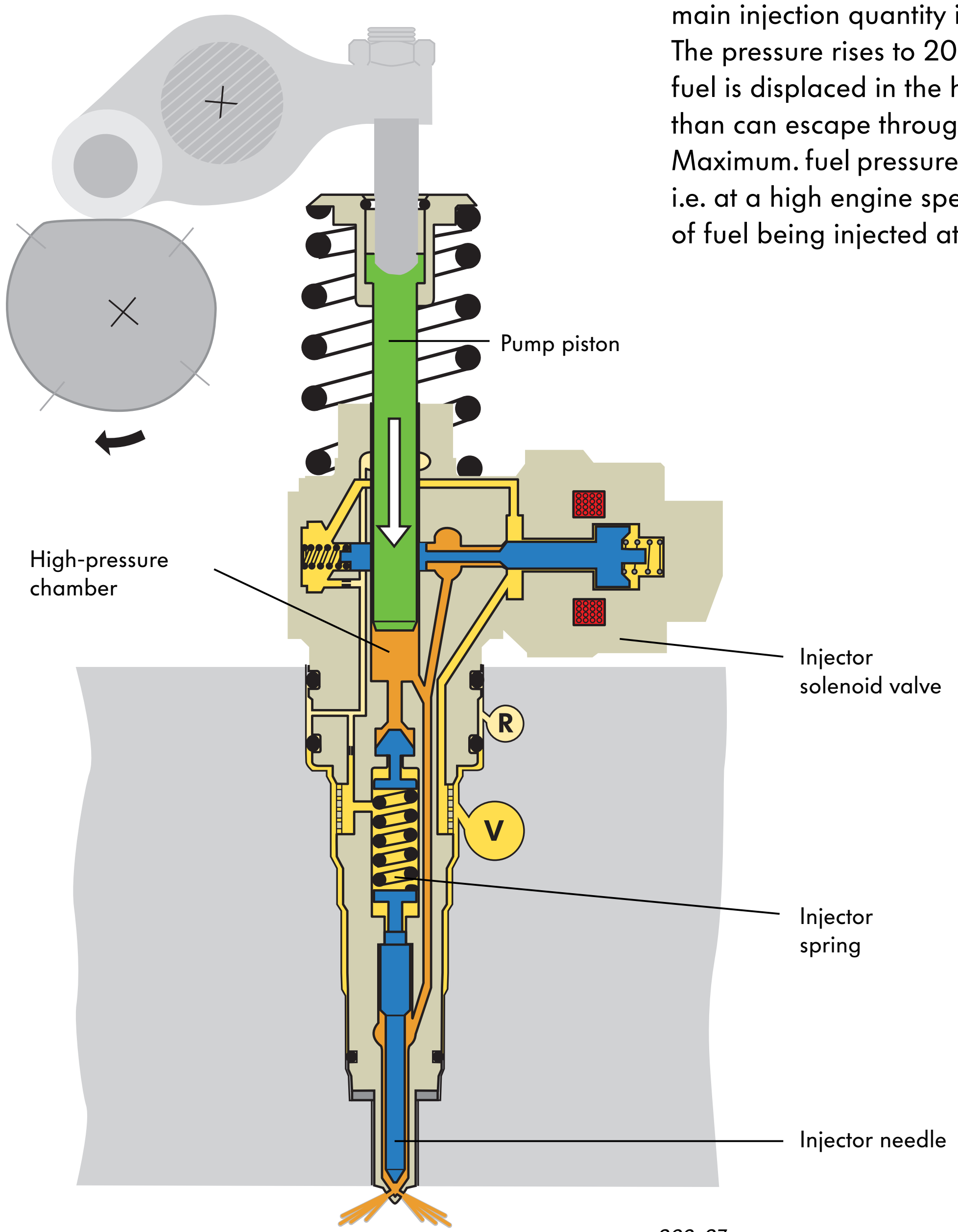
The main injection cycle commences

The pressure in the high-pressure chamber rises again shortly after the injector needle closes. The injector solenoid valve remains closed and the pump piston moves downwards.
At approx. 300 bar, the fuel pressure is greater than the force exerted by the pre-loaded injector spring. The injector needle is again lifted and the main injection quantity is injected.
The pressure rises to 2050 bar, because more fuel is displaced in the high-pressure chamber than can escape through the nozzle holes.
Maximum. fuel pressure is at max. engine output, i.e. at a high engine speed with a large quantity of fuel being injected at the same time.



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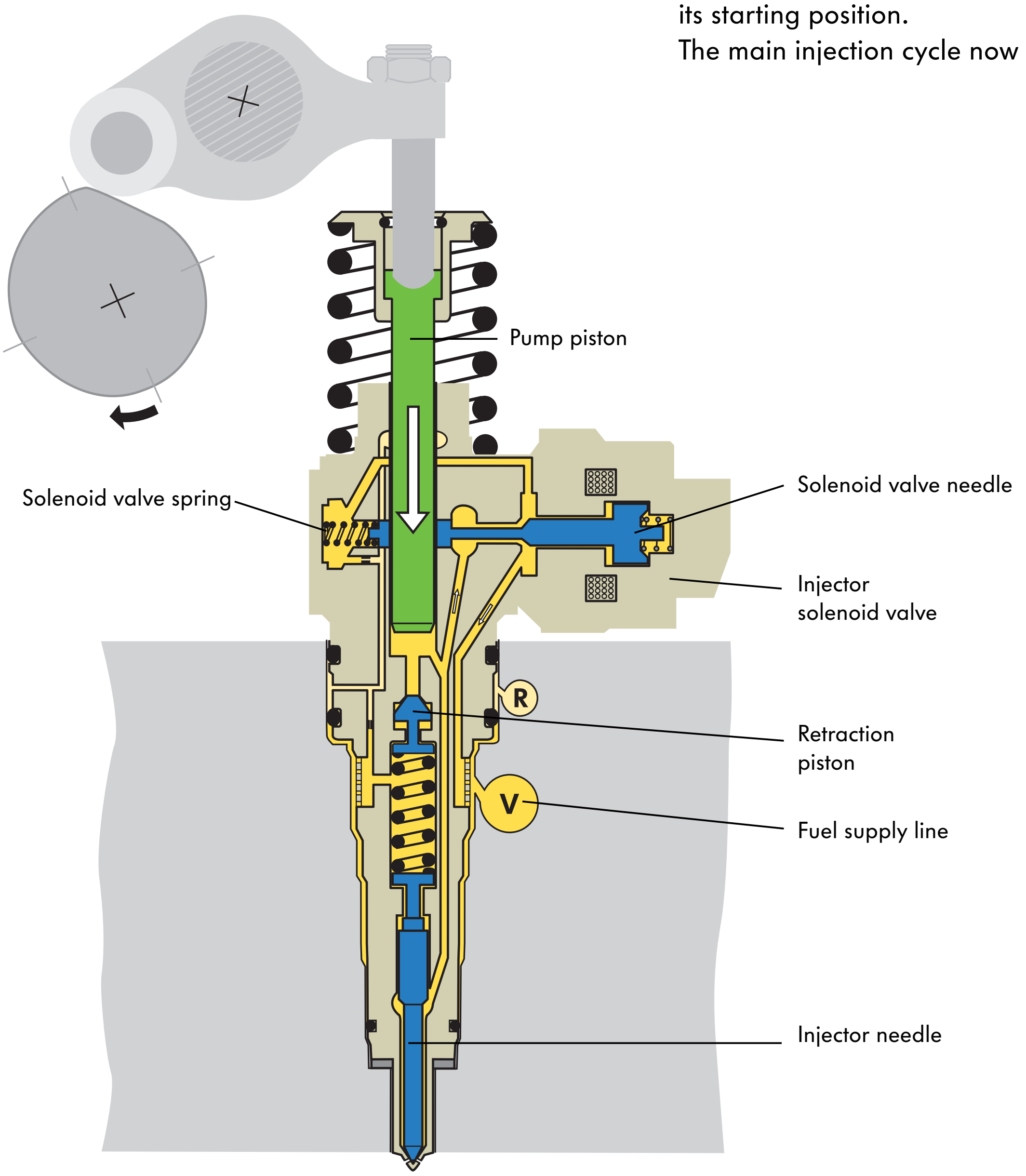
The injection cycle

The main injection cycle ends

The injection cycle ends when the engine control unit stops activating the injector solenoid valve. The solenoid valve spring opens the solenoid valve needle, and the fuel displaced by the pump piston can enter the fuel supply line. The pressure drops. The injector needle closes and the injector spring presses the bypass piston into its starting position.
The main injection cycle now ends.



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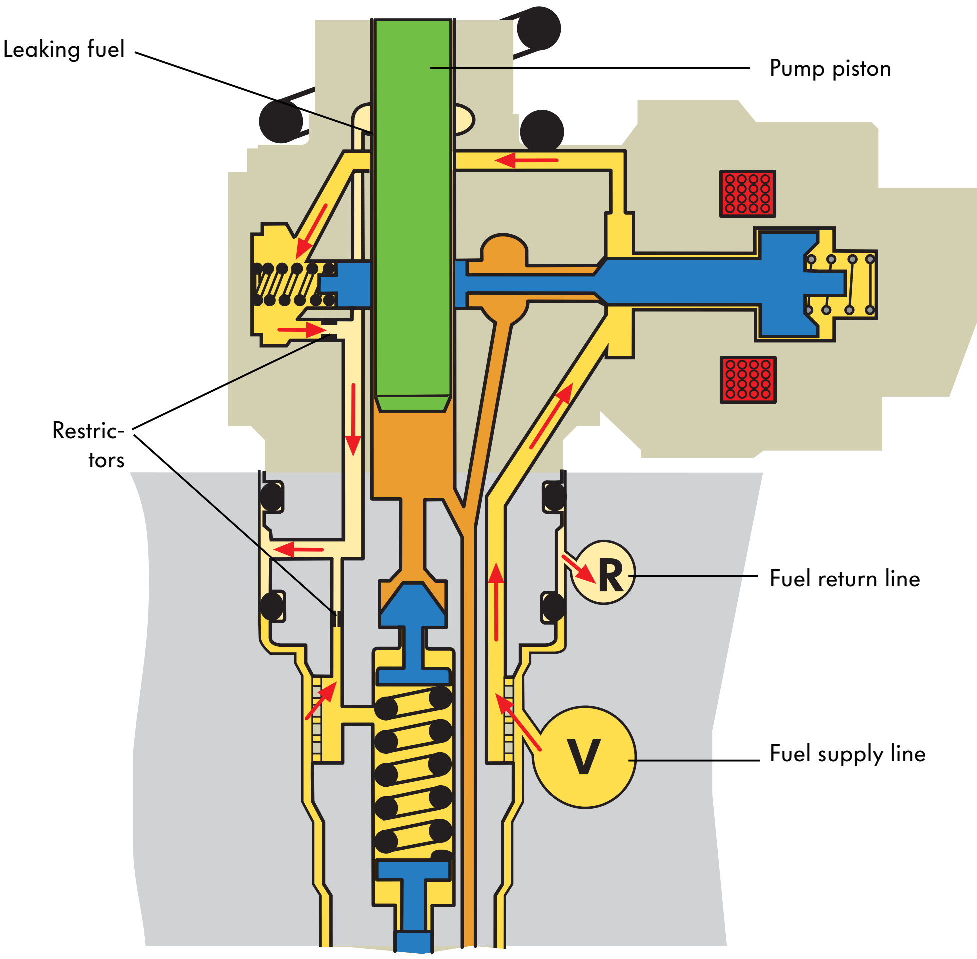
Fuel return in the pump injector

The fuel return line in the pump injector has the following task:

- Cool the pump injector. For this purpose, fuel from the fuel supply line is flushed through the pump injector ducts into the fuel return line.
- Discharge leaking fuel at the pump piston.
- Separate vapour bubbles from the fuel supply line via the restrictors in the fuel return line.



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Fuel supply

The fuel system

A mechanical fuel pump sucks the fuel out of the fuel tank through the fuel filter and pumps it along the supply line in the cylinder head to the pump injector units.

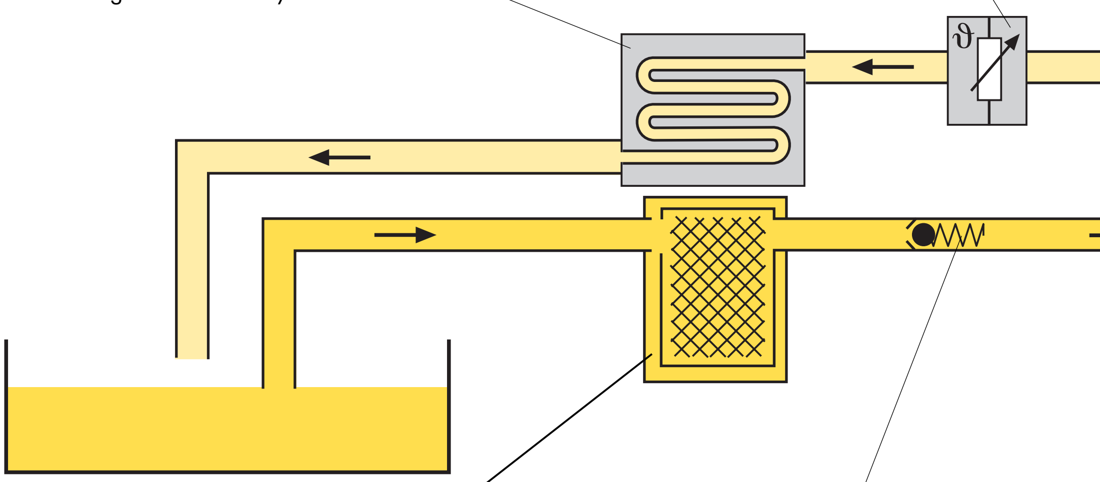
The fuel which is not required for injection is returned to the fuel tank via the return line in the cylinder head, a fuel temperature sensor and a fuel cooler.

The fuel temperature sensor

determines the temperature of the fuel in the fuel return line and sends a corresponding signal to the engine control unit.

The fuel cooler

cools the returning fuel to protect the fuel tank against excessively hot fuel.



The fuel tank

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The fuel filter

protects the injection system against contamination and wear caused by particles and water.

The non-return valve

prevents fuel from the fuel pump flowing back into the fuel tank while the engine is not running (opening pressure=0.2 bar).

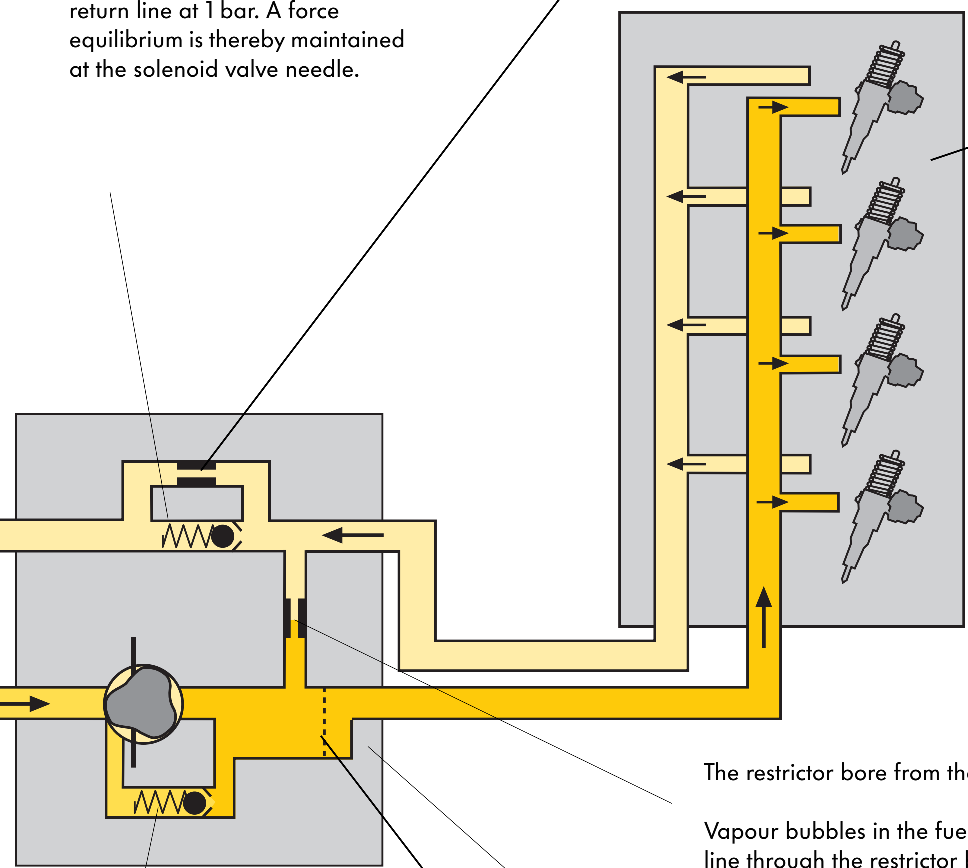
The bypass

If there is air in the fuel system, for example when the fuel tank is empty, the pressure limiting valve remains closed. The air is expelled from the system by the fuel flowing into the tank.

The pressure limiting valve

keeps the pressure in the fuel return line at 1 bar. A force equilibrium is thereby maintained at the solenoid valve needle.

The cylinder head



The restrictor bore from the fuel supply line to the fuel return line

Vapour bubbles in the fuel supply line are separated in the fuel return line through the restrictor bore.

The fuel pump

pumps the fuel from the fuel tank via the fuel filter to the pump injector.

The pressure limiting valve

regulates the fuel pressure in the fuel supply line. The valve opens when the fuel pressure exceeds 7.5 bar, and fuel is fed to the suction side of the fuel pump.

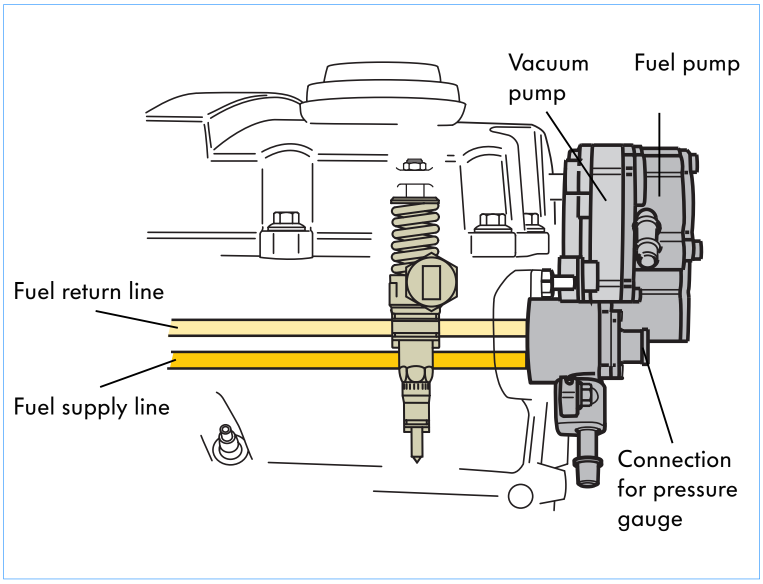
The strainer

has the task of collecting vapour bubbles from the fuel supply line. These vapour bubbles are then separated through the restrictor bore and return line.

Fuel supply

The fuel pump

The fuel pump is located directly behind the vacuum pump at the cylinder head. It has the task of conveying the fuel from the fuel tank to the pump injector.
Both pumps are driven jointly by the camshaft, which is why they are collectively known as a tandem pump.



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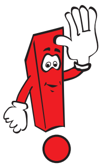
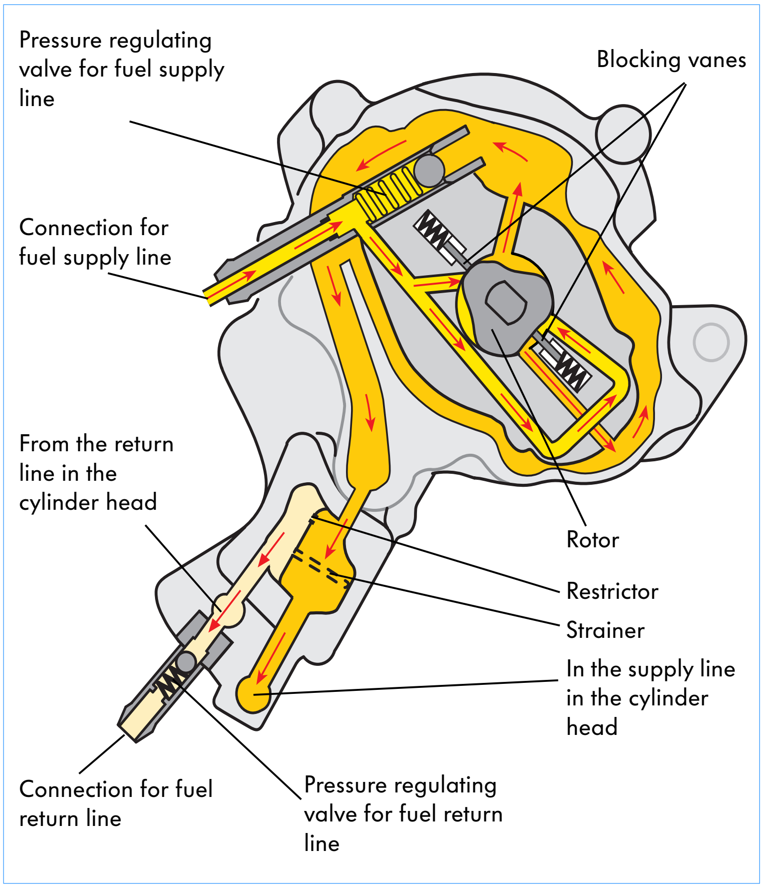


There is a connection for pressure gauge V.A.S. 5187 on the fuel pump for checking the fuel pressure in the supply line. Please observe the instructions in the Workshop Manual.

The fuel pump is a blocking vane-cell pump. With this type of pump, the blocking vanes are pressed against the rotor by the spring pressure. The advantage of this is that the pump delivers fuel even at low engine speeds. Rotary vane pumps do not prime until the engine is running so fast that the vane cells are pressed against the stator by centrifugal force. The fuel ducting system within the pump is designed so that the rotor always remains wetted with fuel even if the tank has been run dry. This makes automatic priming possible.



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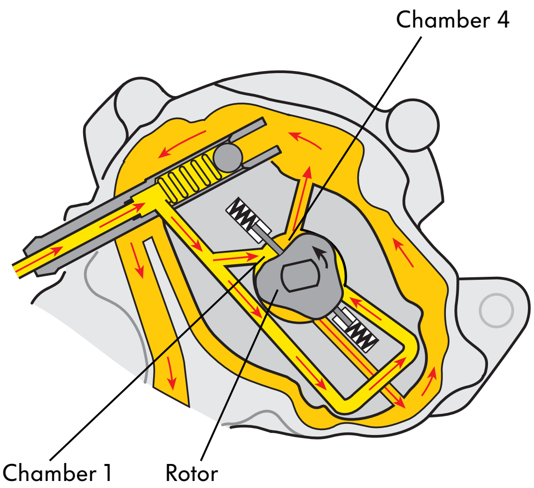
This is how it works:

The fuel pump operates by intaking when the volume increases and delivering when the volume reduces.
The fuel is drawn and pumped into two chambers. The intake chambers and feed chamber are separated from one another by the blocking vanes.

In this figure, fuel is drawn out of chamber 1 and pumped out of chamber 4. The rotational movement of the rotor increases the volume of chamber 1 while the volume of chamber 4 reduces.



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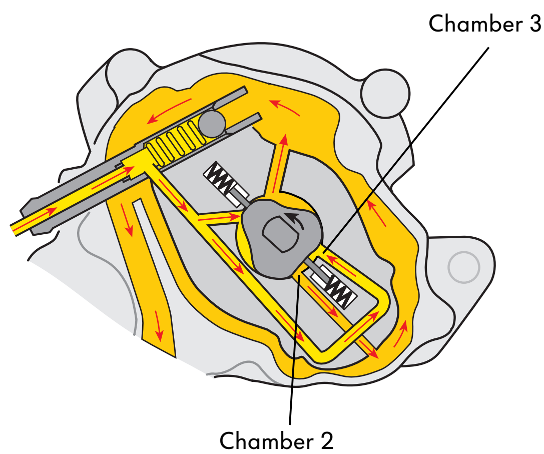
In this figure, the other two chambers are in action. The fuel is pumped out of chamber 2 and drawn out of chamber 3.



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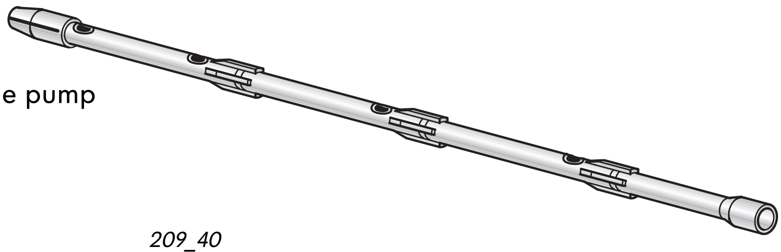
The distributor pipe

A distributor pipe is integrated in the supply line in the cylinder head. It has the task of distributing fuel evenly to the pump injectors.



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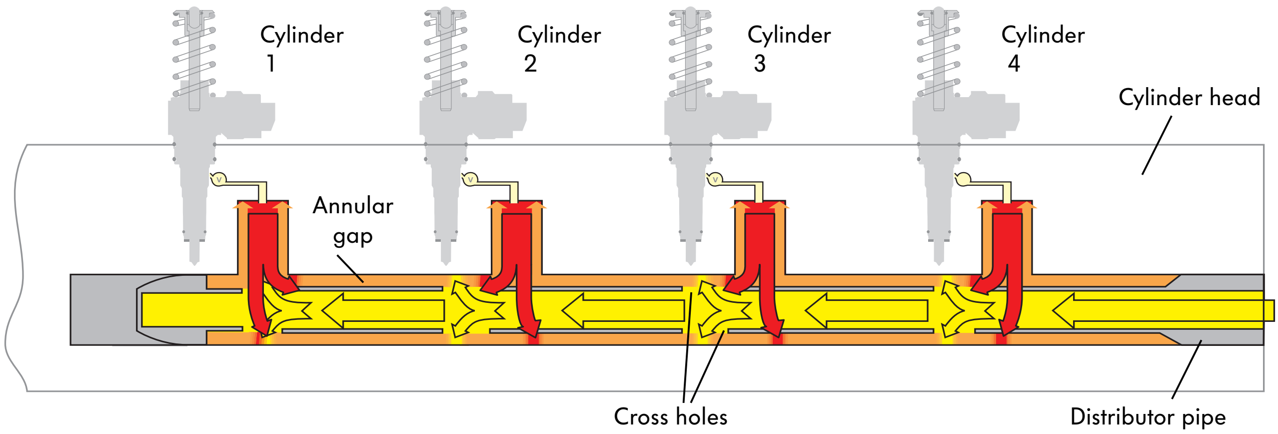

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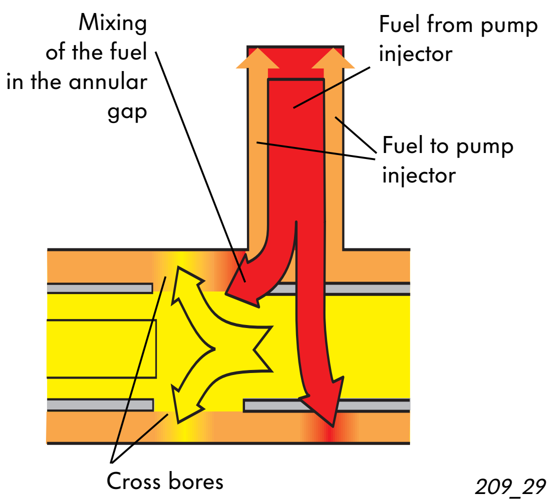
This is how it works:

The fuel pump conveys the fuel into the supply line in the cylinder head.
In the supply line, the fuel flows along the inner side of the distributor pipe towards cylinder 1. The fuel enters the annular gap between the distributor pipe and the cylinder head wall through cross-holes. Here, the fuel mixes with the hot fuel forced back into the supply line by the pump injectors. As a result, the fuel in the supply line running to all cylinders has a uniform temperature. All pump injectors are supplied with the same fuel mass, and the engine runs smoothly.



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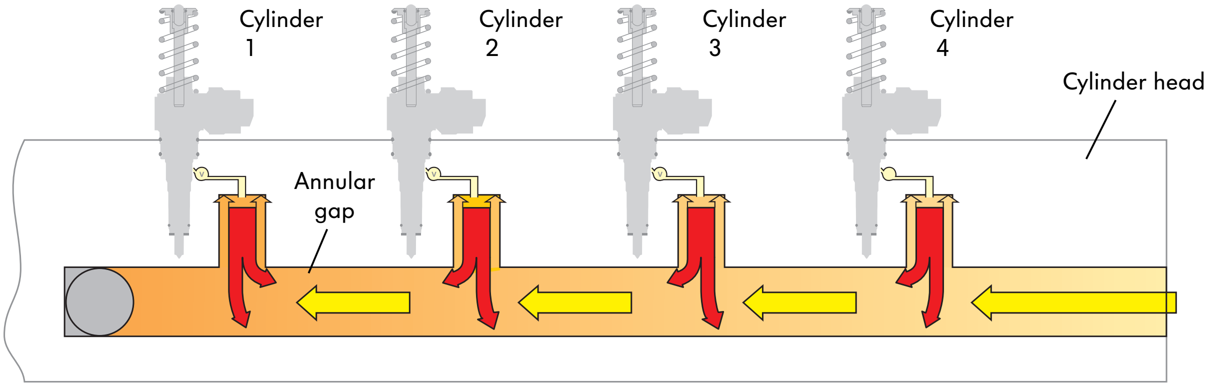
Without a distributor pipe, the fuel temperature at the pump injector would not be uniform. The hot fuel forced back into the supply line by the pump injector is pushed from cylinder 4 towards cylinder 1 by the flowing fuel into the supply line.

As a result, the fuel temperature rises from cylinder 4 to cylinder 1 and the pump injectors are supplied with different fuel masses. The effects of this would make the engine run irregularly and would cause an excessively high temperature in the front cylinders.



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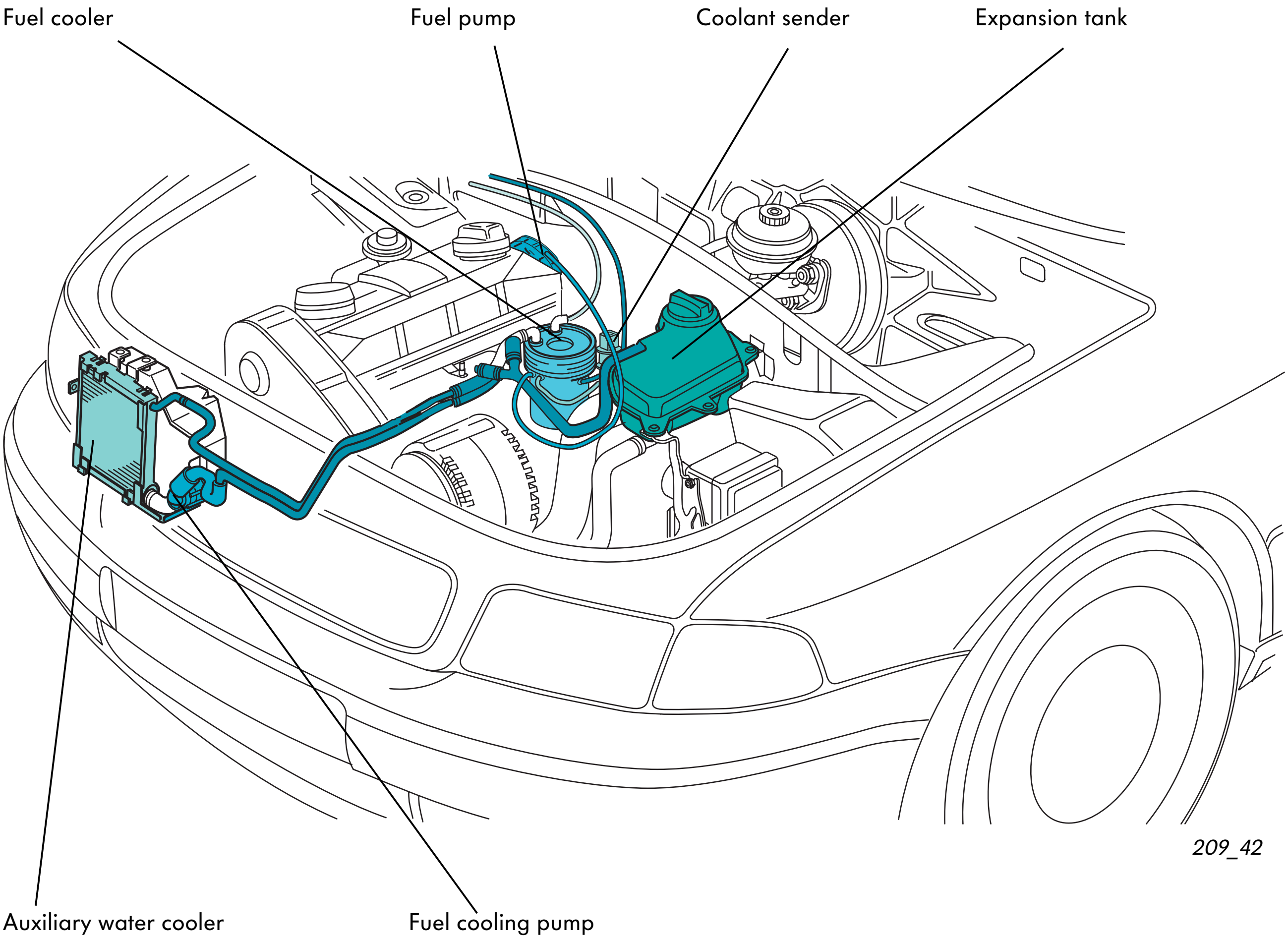
Fuel supply

The fuel cooling system

The high pressure in the pump injector heats up the fuel so intensively that it has to be cooled down before it flows back into the fuel tank.

A fuel cooler is located on the fuel filter.
It cools the returning fuel and thus protects the fuel tank and the fuel level sender against excessively hot fuel.



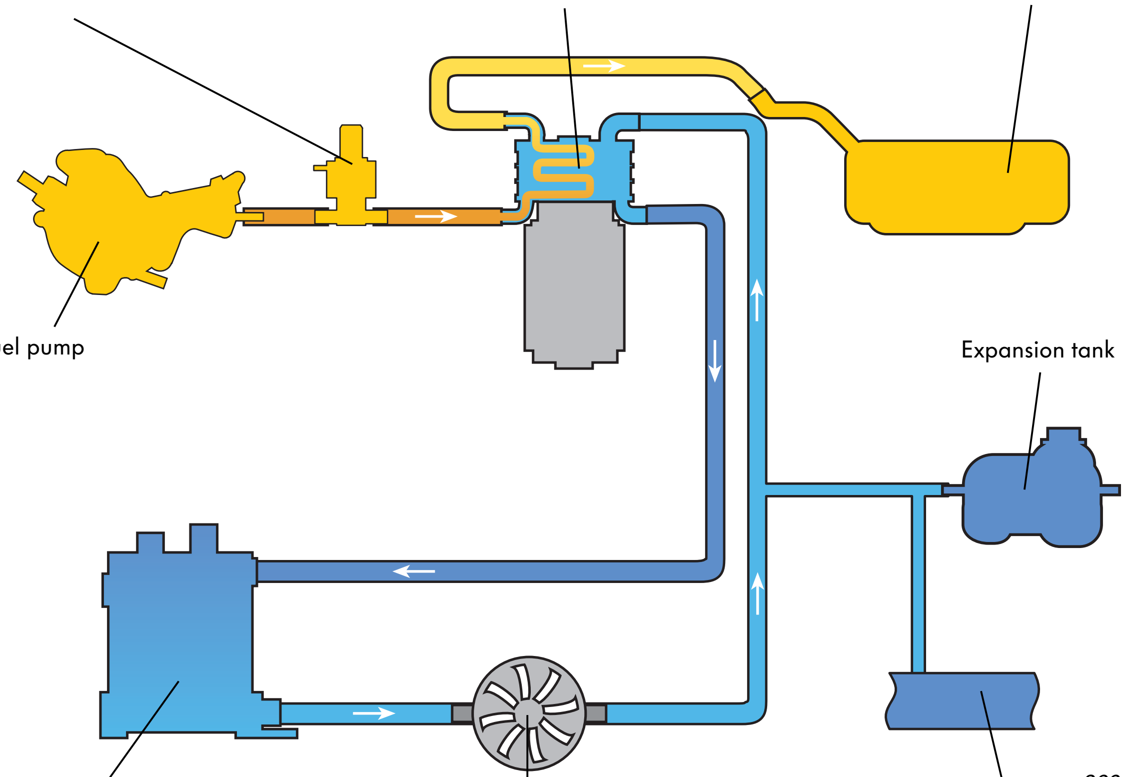
The fuel cooling circuit

The fuel returning from the pump injector flows through the fuel cooler and transfers its high temperature to the coolant in the fuel cooling circuit.
The fuel cooling circuit is separate from the engine cooling circuit. This is necessary since the temperature of the coolant is too high to cool down the fuel when the engine is at operating temperature engine.

The fuel cooling circuit is connected to the engine cooling circuit in the vicinity of the expansion tank. The fuel cooling circuit can thus be filled and changes in volume due to temperature fluctuation can be compensated. The fuel cooling circuit is connected so that the hotter engine cooling circuit does not have a detrimental effect on the fuel cooling circuit.

The fuel cooler

The fuel and coolant flows through the fuel cooler. The temperature of the fuel is transferred to the coolant.



The auxiliary water cooler

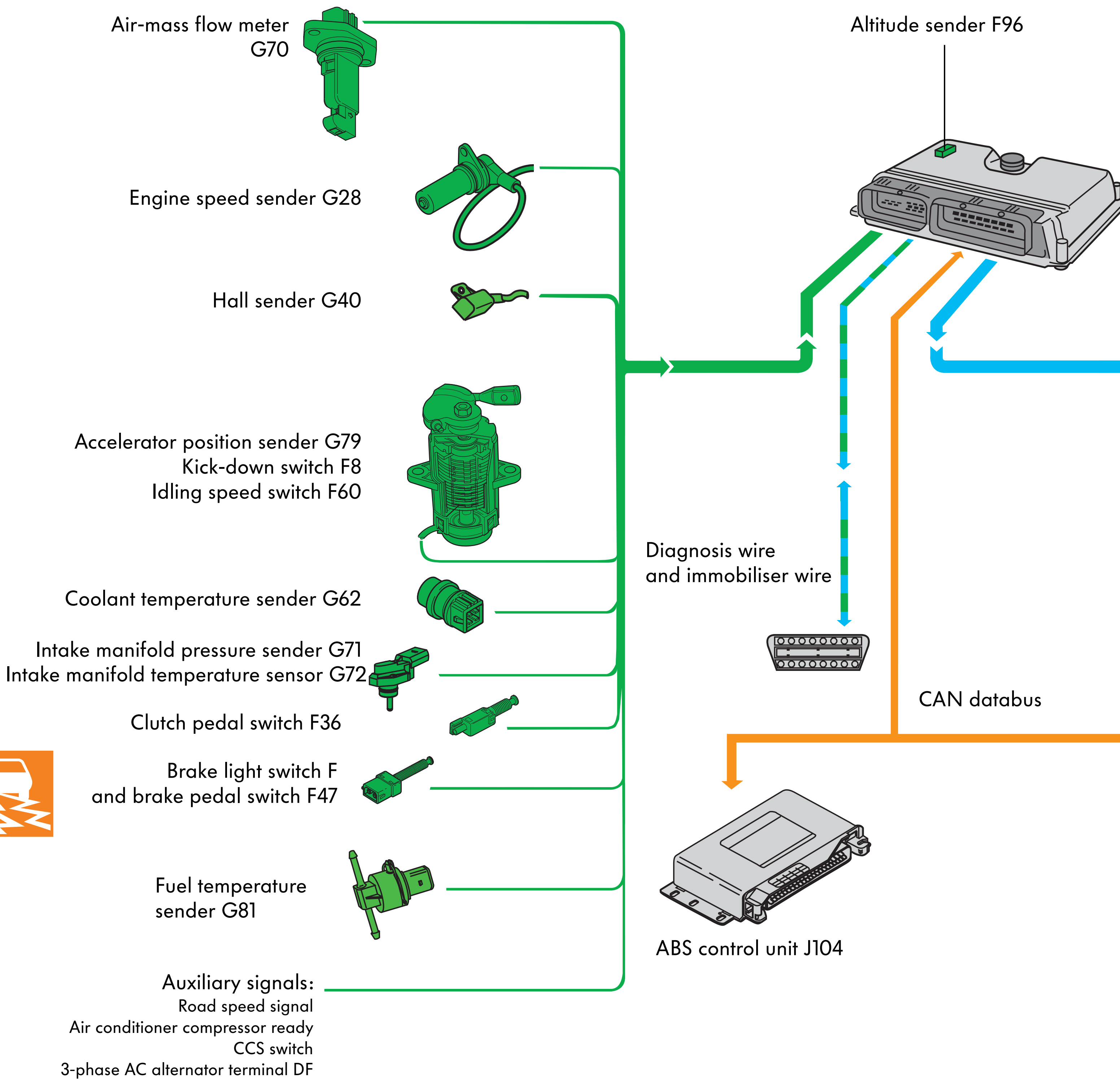
reduces the temperature of the coolant in the coolant circuit. It dissipates the heat of the coolant to the ambient air.

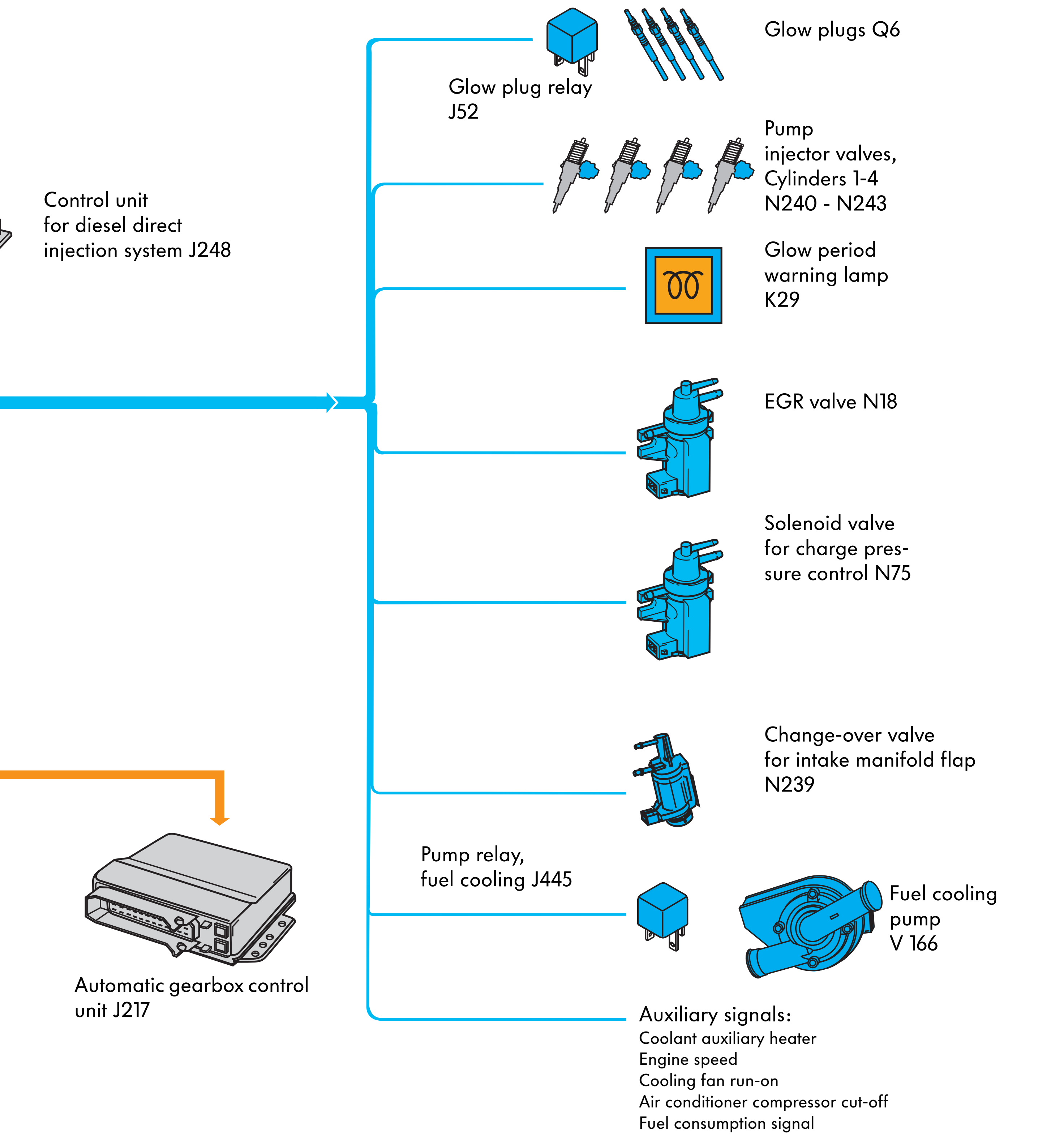
The fuel cooling pump

is an electrical recirculation pump which circulates the coolant in the fuel cooling circuit. It is switched on by the engine control unit via the fuel cooling pump relay at a fuel temperature of 70°C.

Engine management

System overview




Glow plugs Q6
Glow plug relay
J52
Pump
injector valves,
Cylinders 1-4
N240 - N243
Control unit
for diesel direct
injection system J248
Glow period
warning lamp
K29
EGR valve N18
Solenoid valve
for charge pres-
sure control N75
Change-over valve
for intake manifold flap
N239
Pump relay,
fuel cooling J445
Fuel cooling
pump
V 166
Automatic gearbox control
unit J217
Auxiliary signals:
Coolant auxiliary heater
Engine speed
Cooling fan run-on
Air conditioner compressor cut-off
Fuel consumption signal

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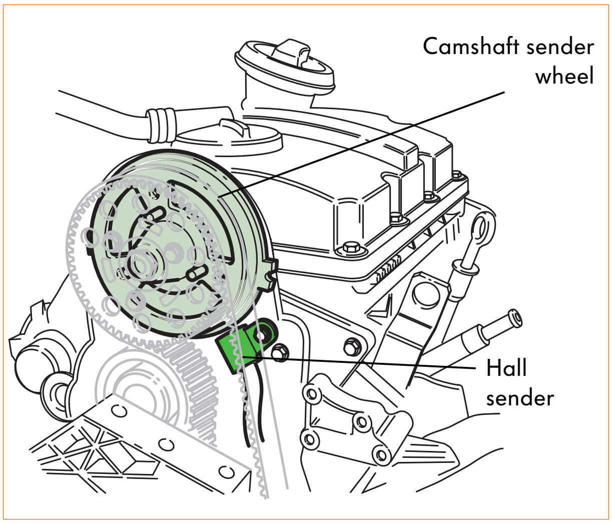
Sensors

Hall sender G40



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The Hall sender is attached to the toothed belt guard below the camshaft gear. It scans seven teeth on the camshaft sender wheel attached to the camshaft gear.

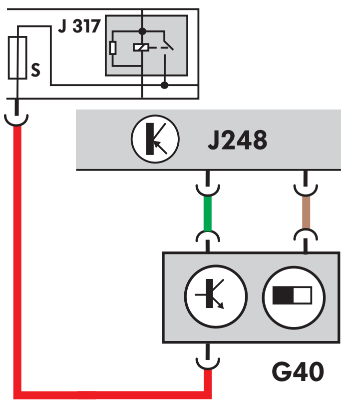
Signal utilisation

The engine control unit uses the signal which the Hall sender generates to recognise the cylinders when starting the engine.

Effects of signal failure

In the event of signal failure, the control unit utilises the signal which the engine speed sender G28 generates.

Electrical circuit



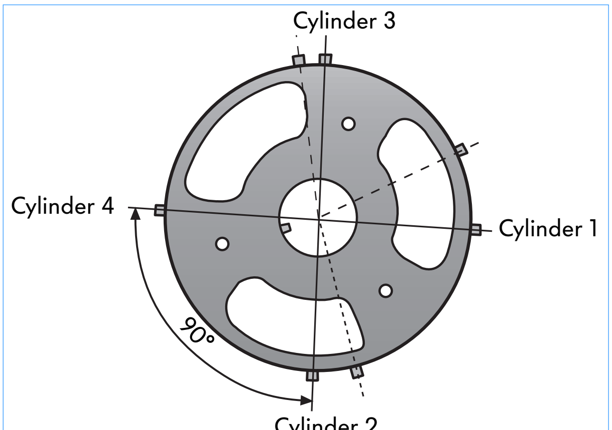
209_55

Cylinder recognition when starting the engine

When starting the engine, the engine control unit must know what cylinder is in the compression stroke in order to activate the correct pump injector valve. For this purpose, it evaluates the signal generated by the Hall sender, which scans the teeth of the camshaft sender wheel and thus determines the camshaft position.

The camshaft sender wheel

Since the camshaft executes one 360° revolution per working cycle, there is a tooth for each individual cylinder on the sender wheel; these teeth are spaced 90° apart.
To enable the teeth to be assigned to the cylinders, the sender wheel has an additional tooth for cylinders 1, 2 and 3 with different spacings.



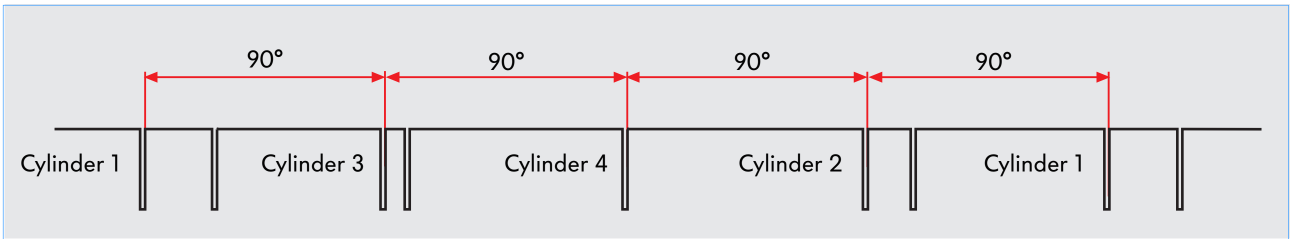
209_94

This is how it works:

Each time a tooth passes the Hall sender, a Hall voltage is induced and transmitted to the engine control unit. Because the teeth are spaced at different distances apart, the Hall voltages occur at different time intervals.

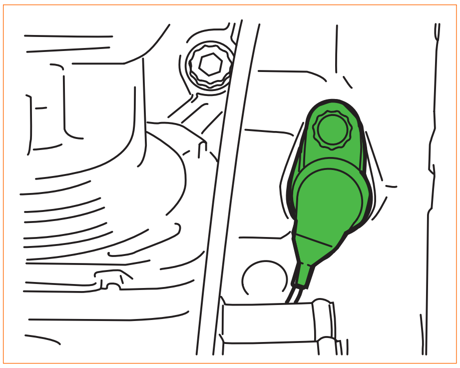
From this, the engine control unit recognises the cylinder and can control the correct injector solenoid valve.

Signal pattern, Hall sender



209_95

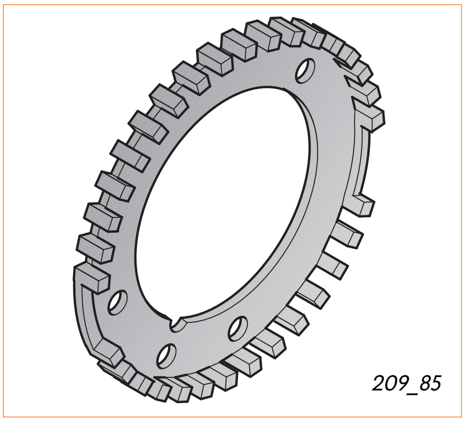
Engine speed sender G28



209_56

The engine speed sender is an inductive sender. It is attached to the cylinder block.

Engine speed sender wheel



209_85

The engine speed sender scans a 60-2-2 sender wheel attached to the crankshaft. The sender wheel has 56 teeth and 2 gaps of 2 teeth on its circumference. The gaps are offset by 180°and serve as a reference mark for determining the crankshaft position.

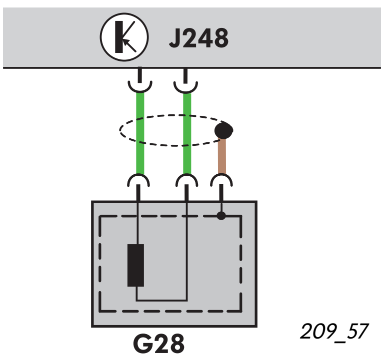
Signal utilisation

The signal generated by the engine speed sender records the engine speed and the exact position of the crankshaft. The injection point and the injection quantity are calculated using this information.

Effects of signal failure

If the signal of the engine speed sender fails, the engine is turned off.

Electrical circuit

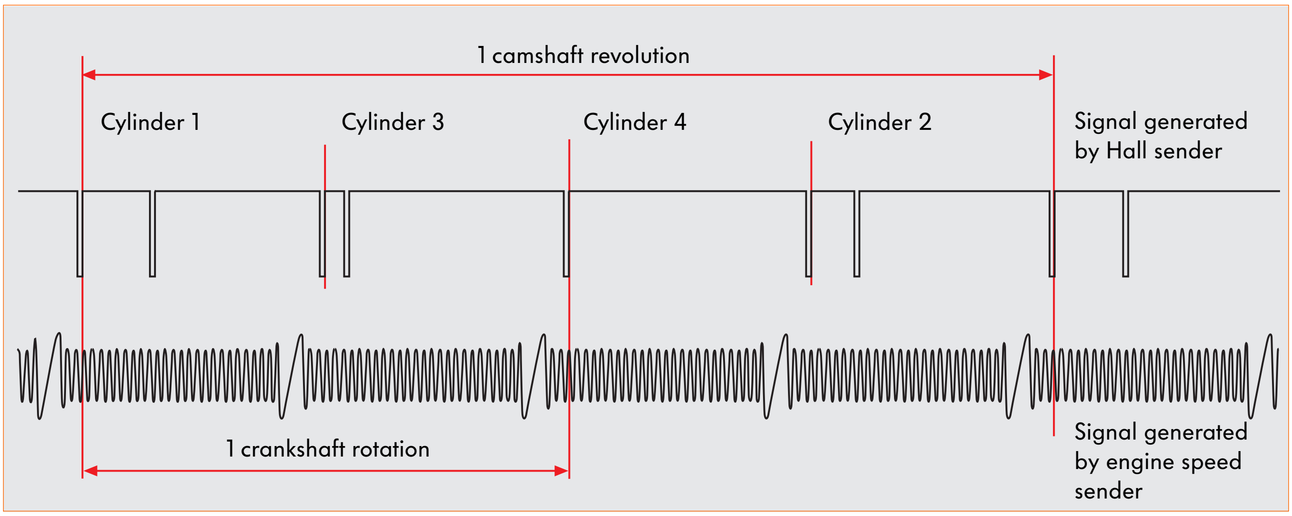


209_57

Function
Quick start recognition

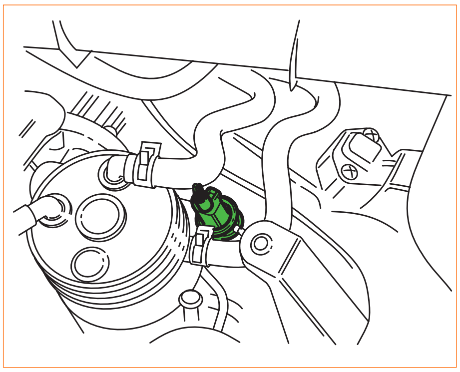
To allow the engine to be started quickly, the engine control unit evaluates the signals generated by the Hall sender and the engine speed sender.
The engine control unit recognises the cylinder from the signal generated by the Hall sender which scans the camshaft sender wheel. Due to the 2 gaps on the crankshaft sender wheel, the engine control unit receives a reference signal after only half a turn of the crankshaft. In this way, the engine control unit can recognise the position of the crankshaft in relation to the cylinders at an early stage and activate the correct solenoid valve to initiate the injection cycle.

Signal pattern, Hall sender and engine speed sender



209_95

Fuel temperature sender G81



209_43

The fuel temperature sender is a temperature sensor with a negative temperature coefficient (NTC). This means that the sensor resistance decreases with increasing fuel temperature. This sensor is located in the fuel return line running from the fuel pump to the fuel cooler and determines the current fuel temperature.

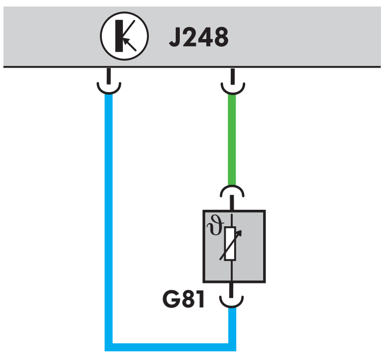
Signal utilisation

The signal generated by the fuel temperature sender is used to recognise the fuel temperature.
The engine control unit requires this signal to calculate the commencement of injection point and the injection quantity so that it can make allowance for the density of the fuel at different temperatures. In addition, the signal is utilised as information for switching on the fuel cooling pump.

Effects of signal failure

In the event of signal failure, the engine control unit calculates a substitute value from the signal generated by coolant temperature sender G62.

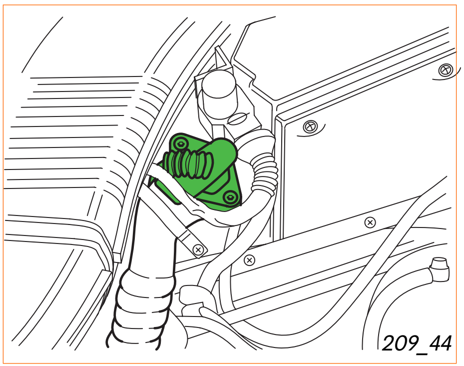
Electrical circuit



209_58

The following sensors have previously been described in other Self-Study Programmes relating to the TDI engine. For this reason, they are not explained in as much detail as the preceding sensors.

Air-mass flow meter G70


209_44

The air-mass flow meter with reverse flow recognition determines the intake air mass. It is located in the intake pipe. The opening and closing actions of the valve produce reverse flows in the induced air mass in the intake pipe.
The hot-film air mass meter with reverse flow recognition recognises the returning air mass and makes allowance for this in the signal it sends to the engine control unit. The air mass is thus measured with high accuracy.

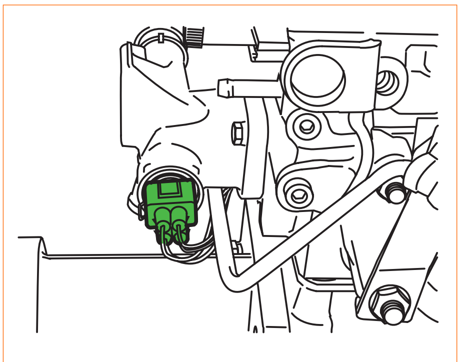
Signal utilisation

The engine control unit utilises the measured values to calculate the injection quantity and the exhaust gas recirculation rate.

Effects of signal failure

If the signal from the air-mass flow meter fails, the engine control unit uses a fixed substitute value.

Coolant temperature sender G62


209_60

The coolant temperature sender is located at the coolant connection on the cylinder head. It sends information about the current coolant temperature to the engine control unit.

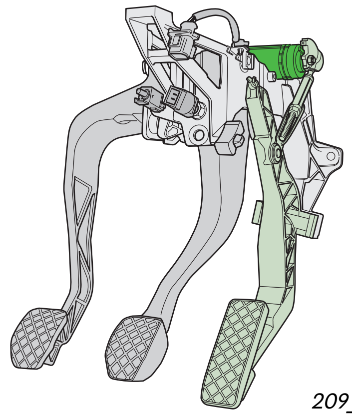
Signal utilisation

The engine control unit uses the coolant temperature as a correction value for calculating the injection quantity.

Effects of signal failure

If the signal fails, the engine control unit uses the signal generated by the fuel temperature sender to calculate the injection quantity.

Accelerator position sender G79
Kick-down switch F8
Idling speed switch F60


209_59

The accelerator position sender is located at the foot controls. The idling speed switch and the kick-down switch are also integrated in the sender.

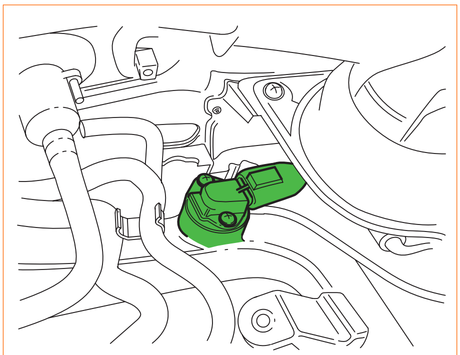
Signal utilisation

The engine control unit can recognise the position of the accelerator pedal from this signal. In vehicles with an automatic gearbox, the kick-down switch indicates to the engine control unit when the driver wants to accelerate.

Effects of signal failure

Without this signal, the engine control unit is unable to recognise the accelerator pedal position. The engine runs on at a higher idling speed to enable the driver to reach the next workshop.

Intake manifold pressure sender G71
Intake manifold temperature sensor G72


209_45

The intake manifold pressure sender and the intake manifold temperature sensor are integrated in the intake pipe in one unit.

Intake manifold pressure sender G71

Signal utilisation

The signal which the intake manifold pressure sender supplies is required to check the charge pressure. The engine control unit compares the actual measured value with the setpoint from the charge pressure map. If the actual value deviates from the setpoint, then the engine control unit adjusts the charge pressure via the solenoid valve for charge pressure control.

Effects of signal failure

The charge pressure can no longer be regulated. Engine performance drops.

Intake manifold temperature sensor G72

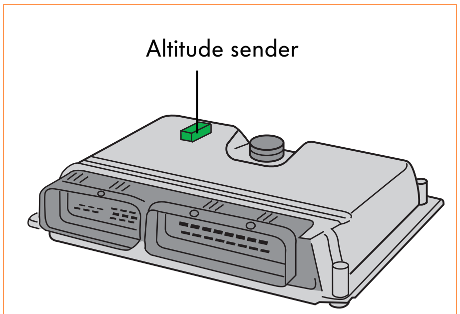
Signal utilisation

The engine control unit requires the signal generated by the intake pipe temperature sender as a correction value for computing the charge pressure. It can then make allowance for the effect of temperature on the density of the charge air.

Effects of signal failure

If the signal fails, the engine control unit uses a fixed substitute value to calculate the charge pressure. This can result in a drop in engine performance.

Altitude sender F96



209_61

The altitude sender is located in the engine control unit.

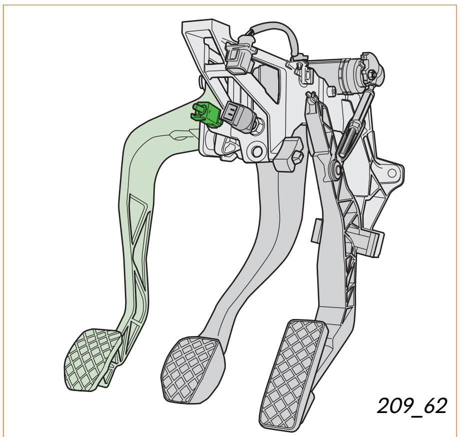
Signal utilisation

The altitude sender sends the momentary ambient air pressure to the engine control unit; this value is dependent on the vehicle's geographical altitude.
With this signal the engine control unit can carry out an altitude correction for charge pressure control and exhaust gas recirculation.

Effects of signal failure

Black smoke occurs at altitude.

Clutch pedal switch F36


209_62

The clutch pedal switch is located at the foot controls.

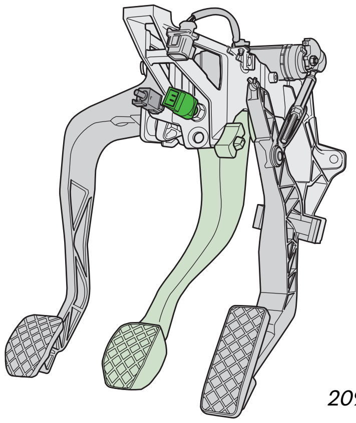
Signal utilisation

The engine control unit recognises from this signal whether the clutch is engaged or disengaged. When the clutch is engaged, injection quantity is reduced briefly to engine prevent shudder when shifting gear.

Effects of signal failure

If the signal from the clutch pedal switch fails, power-off reactions can occur when shifting gear.

Brake light switch F and brake pedal switch F47


209_63

The brake light switch and the brake pedal switch are located on the foot controls in one unit.

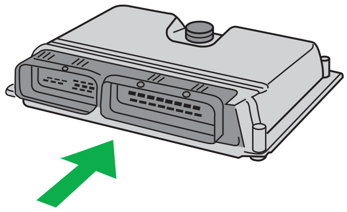
Signal utilisation:

Both switches supply the engine control unit with the “brake activated“ signal. For safety reasons, the engine is regulated when the brake is activated, as the electrical accelerator position sender could be defective.

Effects of signal failure:

If one of the two switches fails, the engine control unit reduces the fuel quantity. Engine performance drops.

Auxiliary-input signal



Road speed signal

The engine control unit receives this signal from the road speed sender.
This signal is used to calculate various functions, the cooling fan run-on and for damping shudder when shifting gear, as well as for checking the cruise control system for proper functioning.

Air conditioner compressor ready

The air conditioner switch sends engine control unit a signal indicating that the air conditioner compressor will shortly be switched on. This enables the engine control unit to increase the idling speed of the engine before the air conditioner compressor is switched on to prevent a sharp drop in engine speed when the compressor starts up.

CCS switch

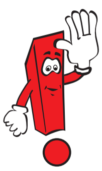
The signal generated by the CCS switch tells the engine control unit that the cruise control system has been activated.

3-phase AC alternator terminal DF

The signal supplied by terminal DF of the 3-phase AC alternator indicates the load state of the 3-phase AC alternator to the engine control unit. Depending on available capacity, the engine control unit can switch on one, two or three glow plugs of the auxiliary heater via the relay for low heater output and the relay for high heater output.

CAN databus

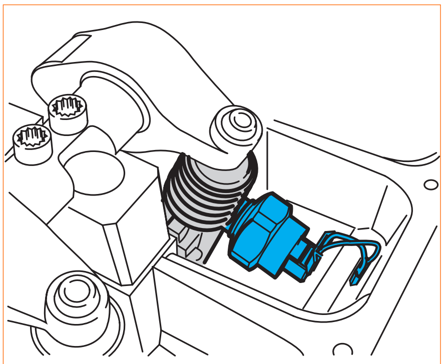
The engine control unit, the ABS control unit and the automatic gearbox control unit interchange information along a CAN databus.
The CAN databus allows large volumes of data to be transferred within a short period of time.



For detailed information regarding the CAN databus, please refer to Self-Study Programme 186.

Actuators

Injector solenoid valves N240, N241, N242, N243


209_64

The injector solenoid valves are attached to the pump injector units by a cap nut.
These solenoid valves are activated by the engine control unit. The engine control unit regulates the commencement of injection point and injection quantity of the pump injector units via the injector solenoid valves.

Commencement of injection point

As soon as the engine control unit activates an injector solenoid valve, the magnetic coil presses the solenoid valve needle down into the valve seat and closes off the path from the fuel supply line to the high-pressure chamber of the pump injector unit. The injection cycle then begins.

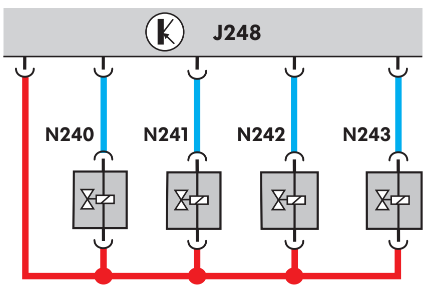
Injection quantity

The injection quantity is dependent on how long the solenoid valve is activated. Fuel is injected into the combustion chamber as long as the injector solenoid valve is closed.

Effects of failure

If an injector solenoid valve fails, the engine will not run smoothly and performance will be lower. The injector solenoid valve has a dual safety function. If the valve stays open, pressure cannot build up in the pump injector. If the valve stays closed, the high-pressure chamber of the pump injector can no longer be filled. In both cases, no fuel is injected into the cylinders.

Electrical circuit



209_65

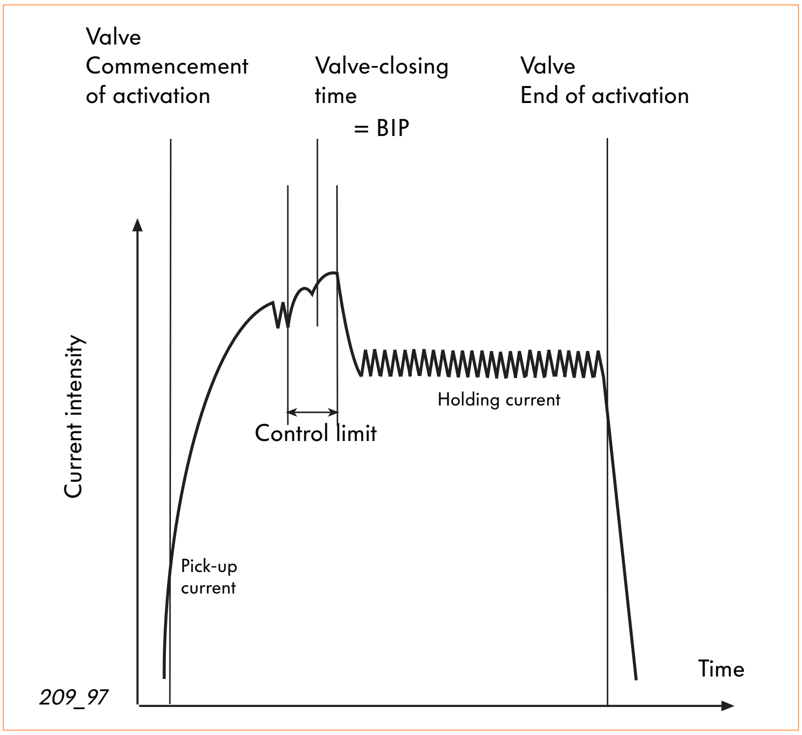
How the injector solenoid valve is monitored

The engine control unit monitors the electrical current curve of the injector solenoid valve. This information serves the engine control unit as feedback on the actual commencement of injection point. The engine control unit can use this feedback to regulate the commencement of injection point and detect malfunctioning of the valve.

This is how it works

The injection cycle is initiated when the injector solenoid valve is activated. A magnetic field is built up, the current intensity increases and the valve closes.
A distinct knee appears in the current curve at the point where the solenoid valve needle makes contact with the valve seat.
This knee point is described as the **BIP** (abbreviation for Beginning of Injection Period).
The BIP indicates to the engine control unit when the injector solenoid valve is fully closed, i.e. the point at which injection commences.

Current curve
Injector solenoid valve



When the valve is closed, the current intensity drops to a constant holding current. When the desired delivery period elapses, the activation cycle ends and the valve opens.

The engine control unit registers the actual closing time of the pump injector valve, or BIP, for the purpose of calculating the activation point of the valve for the next injection cycle. If the actual commencement of injection point deviates from the set value stored in the engine control unit, the point at which activation of the valve begins is corrected.

To be able to detect malfunctioning of the valve, the range within which the engine control unit expects the BIP is scanned and evaluated. This range represents the control limit of the commencement of injection point. When the injector solenoid valve is functioning properly, the BIP lies within the control limit. If a malfunction occurs, then the BIP will lie outside the control limit. In this case, the commencement of injection point is controlled according to fixed values derived from the characteristic curve; the BIP cannot be regulated.

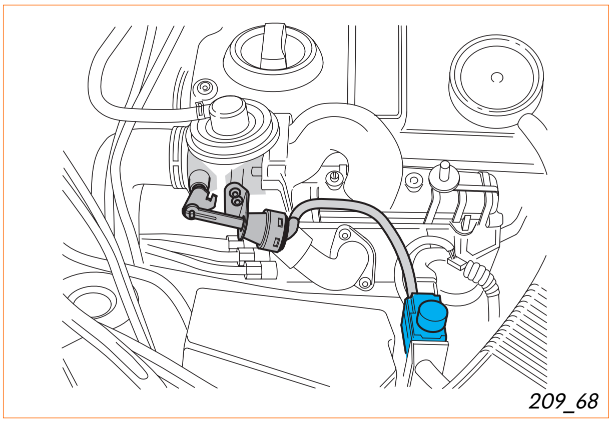
Example

If there is air inside the pump injector, the solenoid valve needle has a low resistance when it closes. The valve closes quickly and the BIP is earlier than expected.

In this case, the self-diagnosis indicates the following fault message:

BIP below control limit

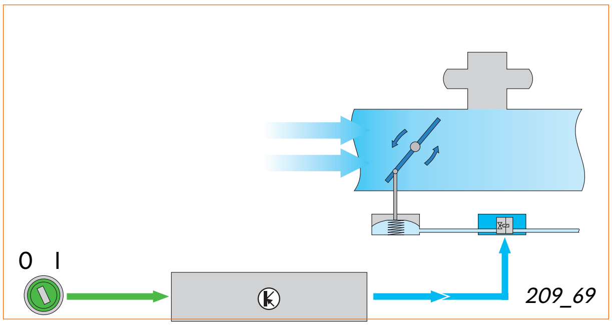
Intake manifold flap change-over valve N239


209_68

The intake manifold flap change-over valve is located in the engine compartment, in the vicinity of the air-mass flow meter. It switches the vacuum for actuating the intake manifold flap in the intake pipe. This stops the engine shuddering when the ignition is turned off.
Diesel engines have a high compression ratio. The engine shudders when the ignition is turned off on account of the high compression pressure of the induced air.

The intake manifold flap interrupts the air supply when the engine is turned off. As a result, little air is compressed and the engine runs softly to a halt.

This is how it works



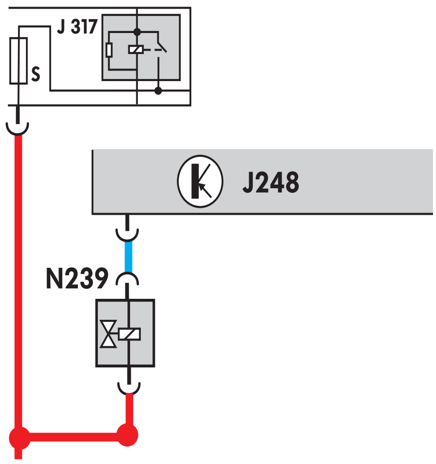
209_69

If the engine is turned off, the engine-control unit sends a signal to the intake manifold flap change-over valve. The change-over valve then switches the vacuum for the vacuum box. The vacuum box closes the intake manifold flap.

Effects of failure

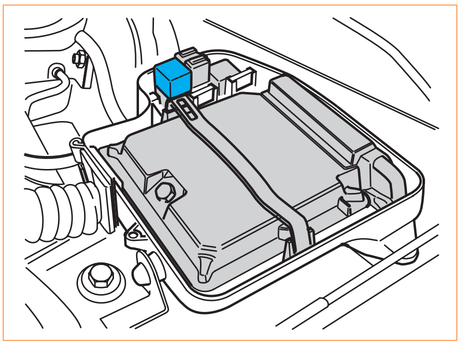
If the intake manifold flap change-over valve fails, the intake manifold flap stays open.

Electrical circuit



209_70

Fuel cooling relay J445

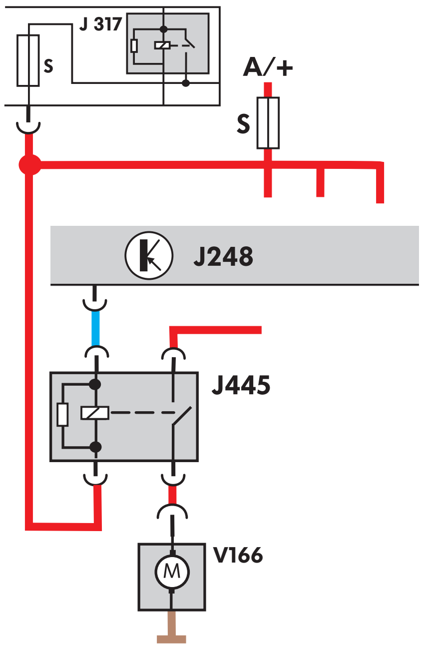


The fuel cooling relay is located in the control unit housing. It is activated by the engine control unit at a fuel temperature of 70°C and switches the working current for the fuel cooling pump.

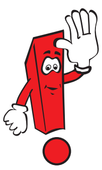
Effects of failure

If the relay drops out, the fuel flowing back from the pump injector to the fuel tank will not be cooled. The fuel tank and the fuel level sender can become damaged.

Electrical circuit



209_72

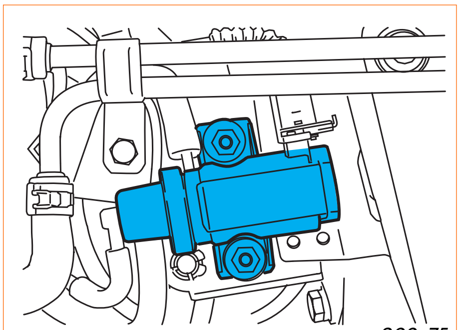


The actuator diagnosis function in the self-diagnosis can be used to check whether the fuel cooling relay has been activated by the engine control unit.

Engine management system

The following actuators have already been described in other Self-Study Programmes dealing with the TDI engine. For this reason, they are not explained in as much detail as the preceding actuators.

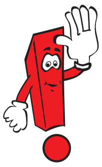
Solenoid valve for charge pressure control N75


209_75

The engine has a variable turbine geometry for adopting the charge pressure optimally to the actual driving conditions. The solenoid valve for charge pressure control is activated by the engine control unit.
The vacuum in the vacuum box for vane adjustment is set depending on the pulse duty factor. The charge pressure is regulated in this way.

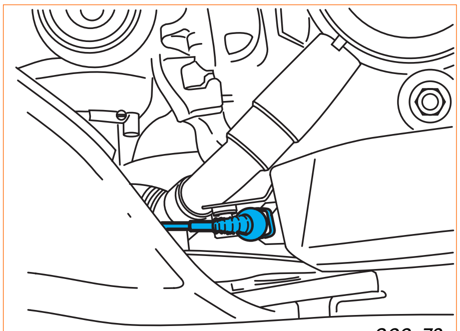
Effects of failure

Atmospheric pressure is present at the vacuum box. As a result, the charge pressure is lower and engine performance is lower.



For detailed information regarding the variable turbine geometry, please refer to Self-Study Programme 190.

EGR valve N18

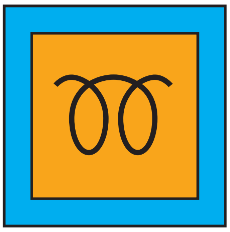

209_73

The exhaust gas recirculation system mixes a portion of the exhaust gases with the fresh air supplied to the engine via the EGR valve. This lowers the combustion temperature and reduces the formation of nitrogen oxides. The engine control unit activates the exhaust gas recirculation valve. The vacuum for exhaust gas recirculation valve adjustment is set depending on the pulse duty factor of the signal. The quantity of exhaust gases returned is controlled in this way.

Effects of failure

Engine performance is lower and exhaust gas recirculation is not assured.

Warning lamp for glow period K29


209_77

The warning lamp for glow period is located in the dash panel insert.

It has the following tasks:

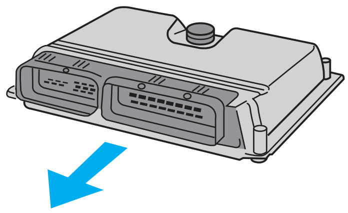
- It signals to the driver that the pre-starting glow phase is in progress. In this case, it is lit continuously.

- If a component with self-diagnostic capability becomes faulty, the warning lamp flashes.

Effects of failure:

The warning lamp comes on and does not flash.
A fault message is stored to the fault memory.

Auxiliary output signals



Coolant auxiliary heater

Thanks to its high efficiency, the engine develops so little waste heat that sufficient heat output may not be available in certain circumstances. In countries with cold climates, therefore, an electrical auxiliary heater is used to heat the coolant at low temperatures.
The auxiliary heater comprises three glow plugs. They are attached to the coolant connection on the cylinder head. The engine control unit utilises this signal to activate the relays for low and high heat output. Therefore, one, two or all three glow plugs for coolant are switched on depending on the available capacity of the 3-phase AC alternator.

Engine speed

This signal serves as information on engine speed for the rev counter in the dash panel insert.

Cooling fan run-on

The run-on period of the cooling fan is controlled according to a characteristic curve stored in the engine control unit. It is calculated from the current coolant temperature and the load state of the engine during the previous driving cycle. The engine control unit uses this signal to activate the relay for radiator fan setting 1.

Air conditioner compressor cut-off

To reduce engine load, the engine control unit switches the air conditioner compressor off in the following conditions:

- after every starting cycle (for approx. 6 seconds)
- under rapid acceleration from the bottom end of the rev band
- at coolant temperatures in excess of +120°C
- in the emergency running program

Fuel consumption signal

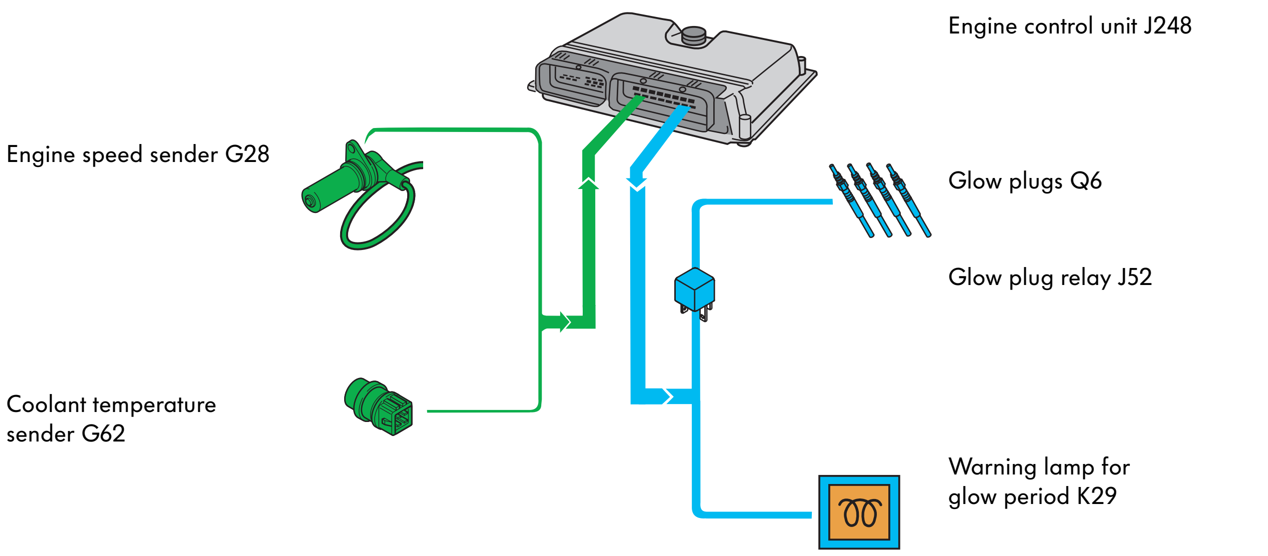
This signal serves as information on fuel consumption for the multifunctional display in the dash panel insert.

Glow plug system

The glow plug system makes the engine easier to start at low temperatures. The engine control unit switches it on when the coolant temperature drops below +9°C.
The glow plug relay is activated by the engine control unit. The engine control unit then switches on the working current for the glow plugs.

The system overview shows you what sensors use signals for the glow plug system and what actuators are activated.

System overview of glow plug system



209_99

The glow process is divided into two phases.

Glow phase

After he ignition is turned on, the glow plugs are switched on at a temperature of below +9°C .
The warning lamp for glow period comes on.
The warning lamp goes out at the end of the glow cycle and the engine can be started.

Afterglow phase

The afterglow phase takes place whenever the engine is started, irrespective of whether it is preceded by a glow phase or not.
This reduces combustion noise, improves idling quality and reduces hydrocarbon emission.
The afterglow phase lasts no more than four minutes and is interrupted when the engine speed
rises above 2500rpm.

Engine management system

Function diagram

Components

E45 CCS switch

F Brake light switch
F8 Kick-down switch
F36 Clutch switch
F47 Brake pedal switch
F60 Idling speed switch

G28 Engine speed sender
G40 Hall sender
G62 Coolant temperature sender
G70 Air-mass flow meter
G71 Intake manifold pressure sender
G72 Intake manifold temperature sensor
G79 Accelerator position sender
G81 Fuel temperature sender

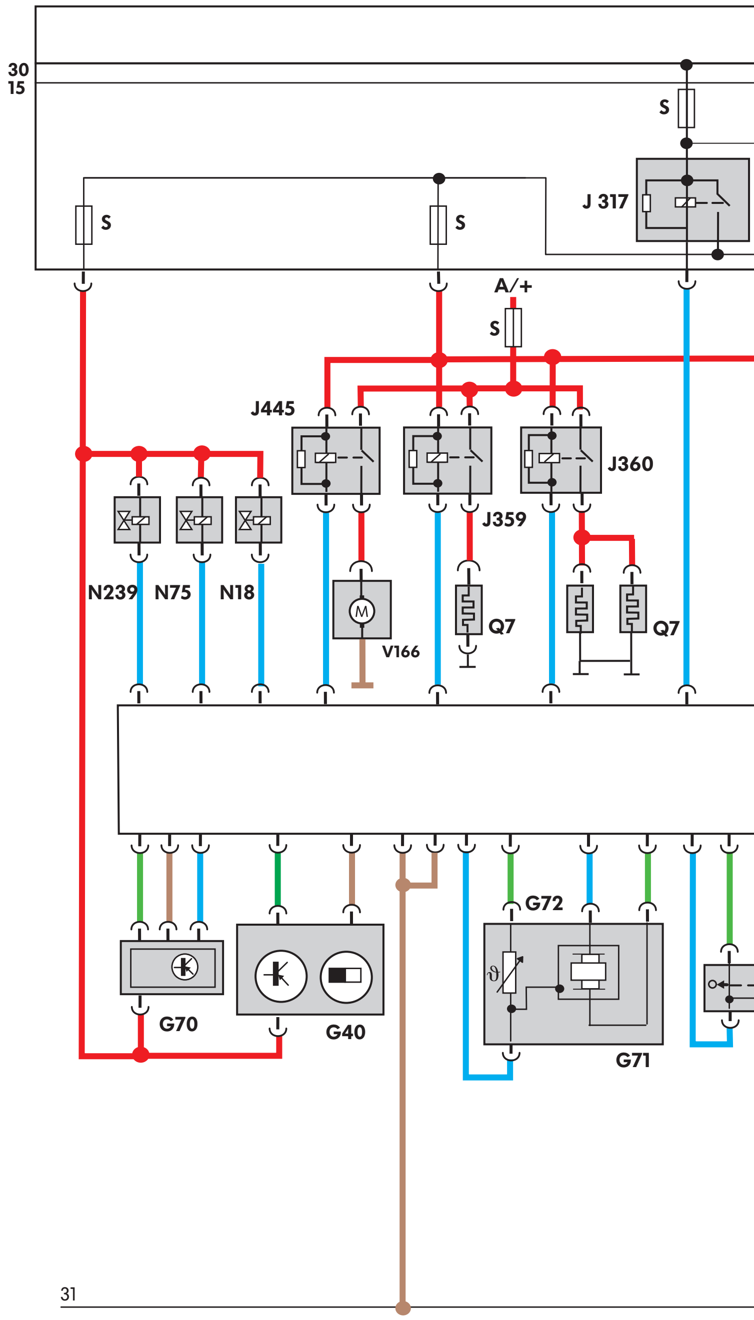
J52 Glow plug relay
J248 Control unit for diesel direct injection system

J317 Voltage supply relay
J359 Low heat output relay
J360 High heat output relay
J445 Pump relay, fuel cooling

N18 EGR valve
N75 Solenoid valve for charge pressure control
N239 Intake manifold flap change-over valve
N240 No. 1 cylinder unit injector solenoid valve
N241 No. 2 cylinder unit injector solenoid valve
N242 No. 3 cylinder unit injector solenoid valve
N243 No. 4 cylinder unit injector solenoid valve

Q6 Glow plugs (engine)
Q7 Glow plugs (coolant)

V166 Fuel cooling pump

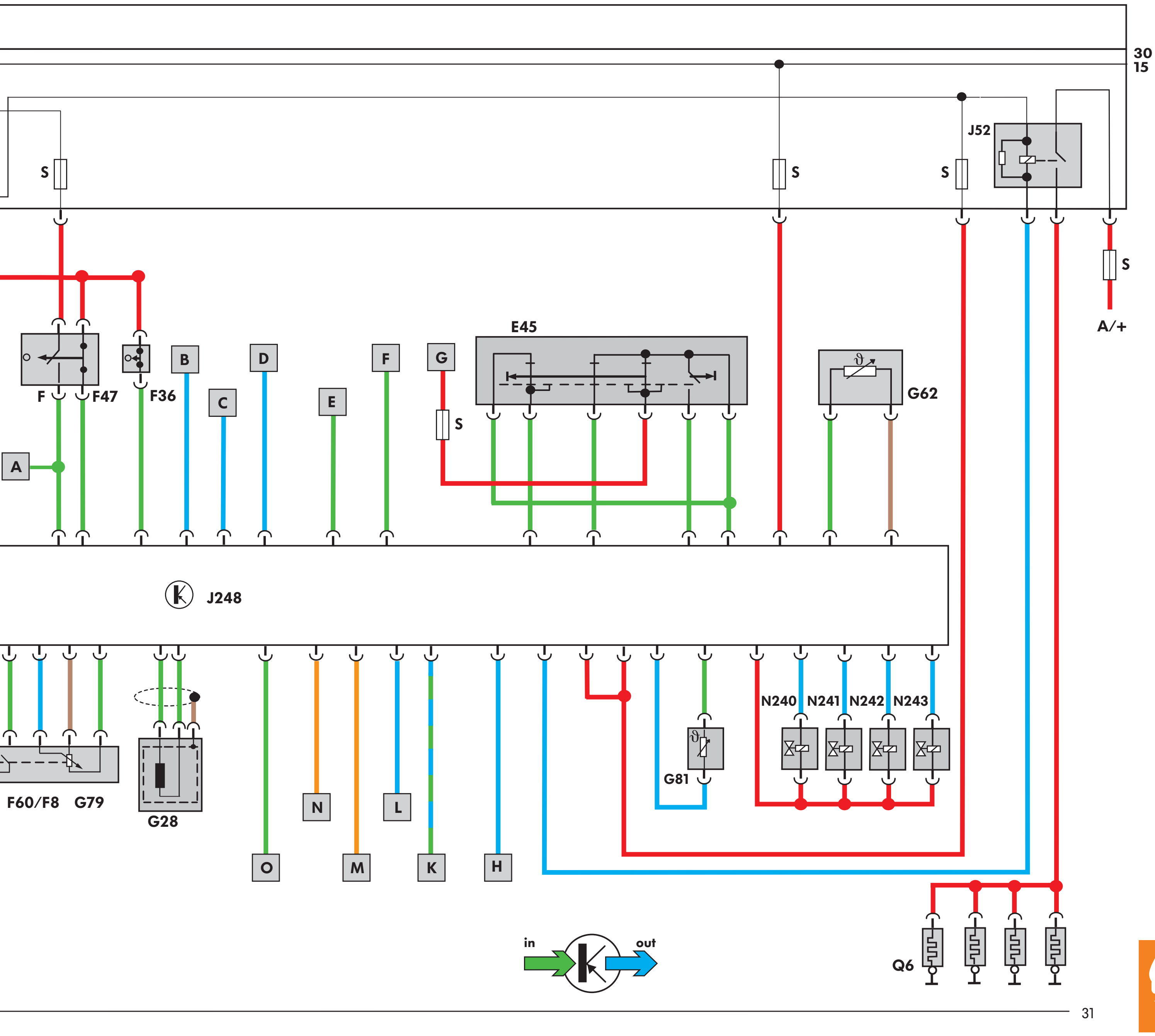


Auxiliary signals

A Brake lights
B Fuel consumption signal
C Engine speed signal
D Air conditioner compressor cut-off
E Air conditioner compressor readiness

F Road speed signal
G CCS voltage supply

H Cooling fan run-on
K Diagnosis and immobiliser wire



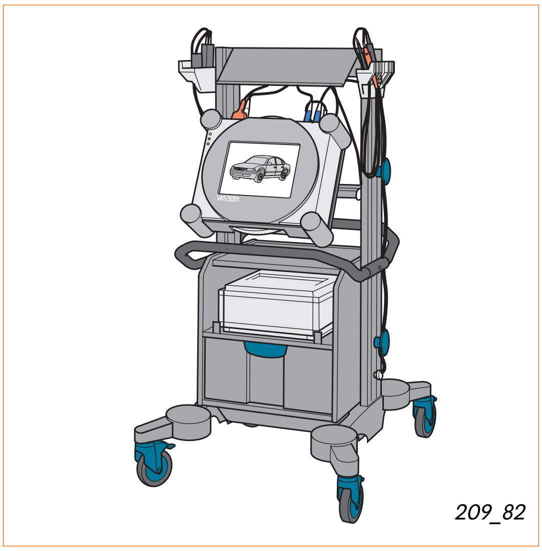
209_80

L	Glow period control
M	CANbus Low
N	CANbus High
O	Terminal DF

- Input signal
- Output signal
- Positive
- Earth
- CAN databus

Self-diagnosis

The following functions can be read out using the V.A.S. 5051 self-diagnosis, measurement and information system:

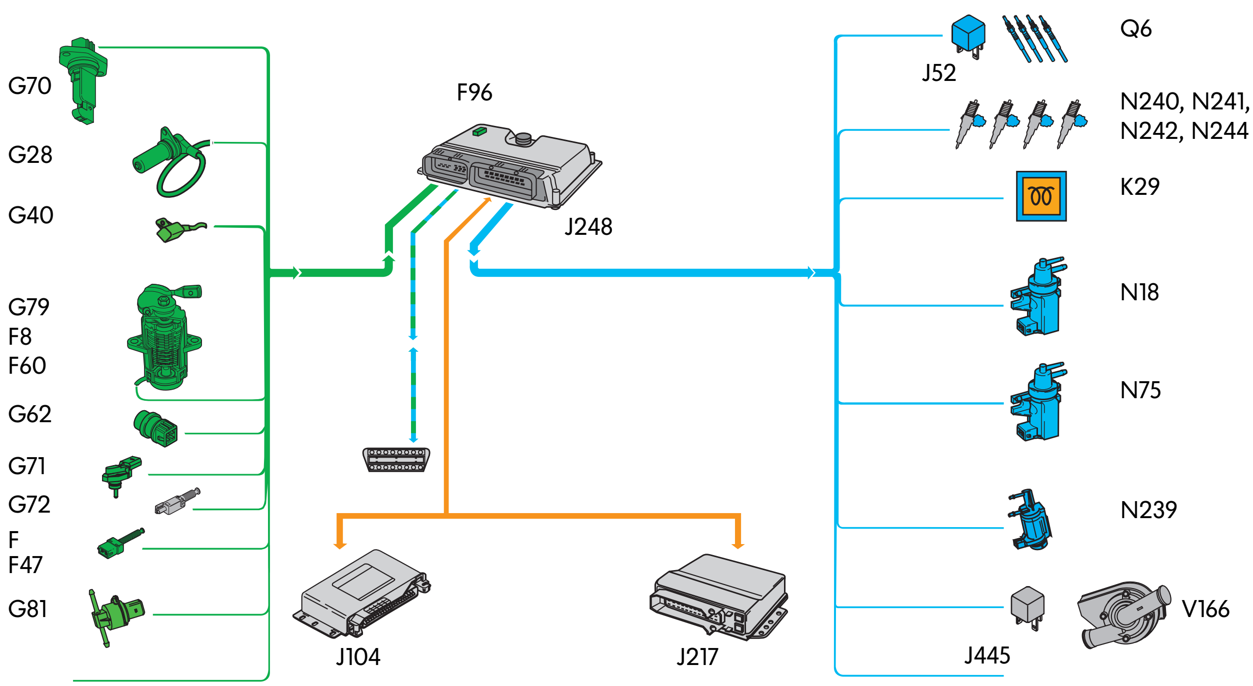


209_82

01	Interrogate control unit version
02	Interrogate fault memory
03	Actuator diagnosis
04	Basic adjustment
05	Erase fault memory
06	End of output
07	Encode control unit
08	Read measured value block

Function 02 Interrogate fault memory

The colour coded components are stored to the fault memory by the self-diagnosis function.

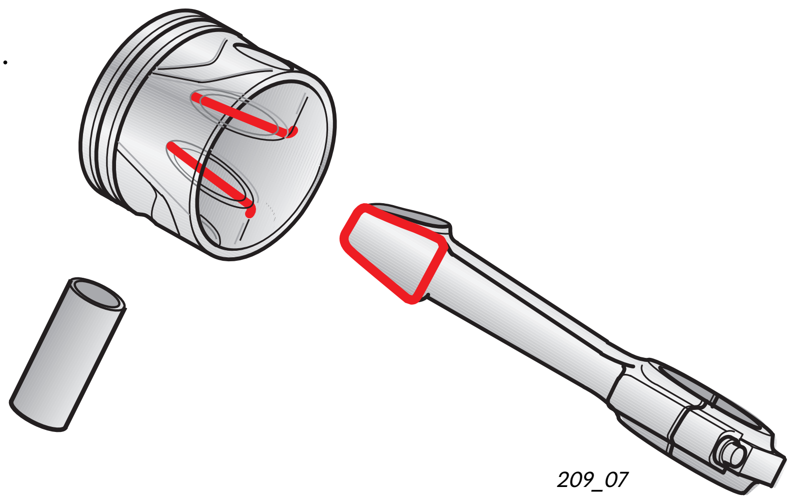


209_81

To make allowance for the fact that the combustion pressure is higher than in the base engine, the following modifications were made to the engine mechanicals:

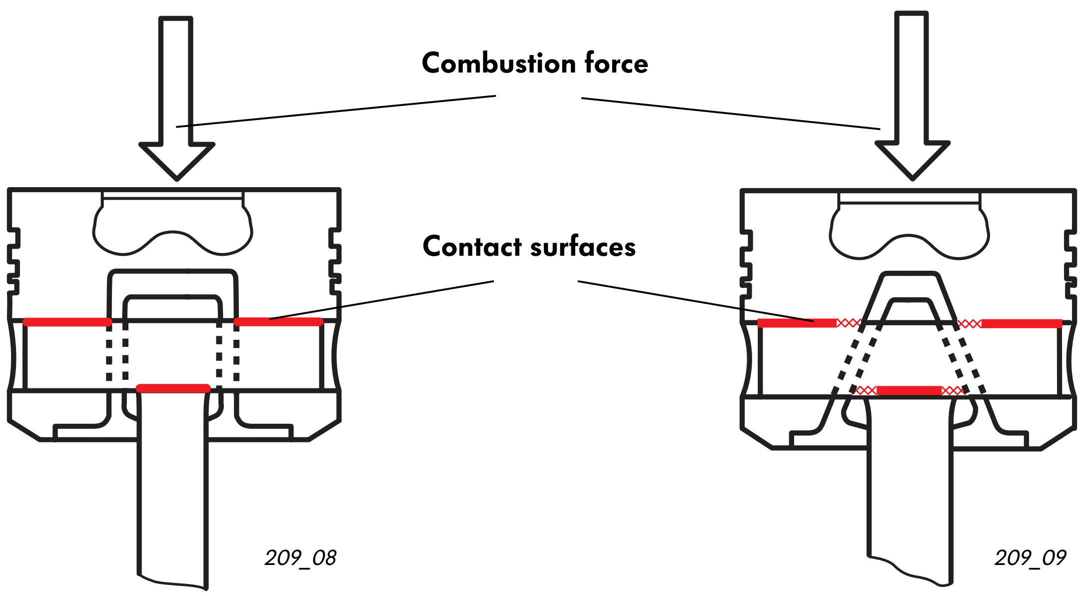
Trapezoidal piston and conrod

The piston hub and the conrod eye are trapezoidal.



Force distribution in a parallelogram-shaped piston and conrod

Force distribution in a trapezoidal piston and conrod



In comparison with the conventional link between the piston and the conrod, the conrod eye and the piston hub have a larger contact surface area at the piston pin owing to their trapezoidal shape.

The combustion forces are consequently distributed over a large area, and this relieves the load on the piston pin and conrod.

The toothed belt drive

High pump forces are required to generate an injection pressure of up to 2000 bar.
These forces subject the components of the toothed belt drive to high loads.

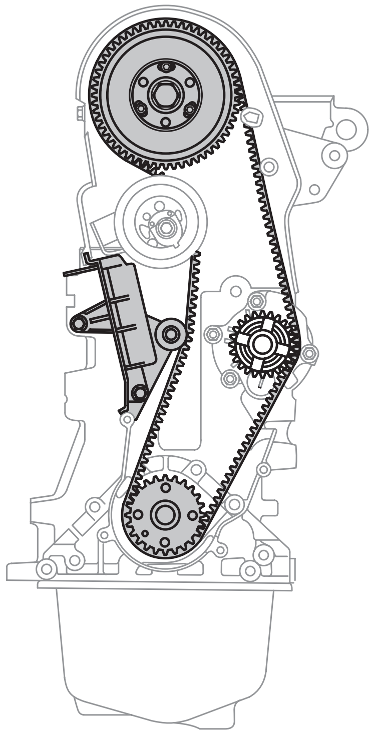
For this reason, the following measures were taken to relieve the load on the toothed belt:

- A vibration absorber integrated in the camshaft gear reduces vibration in the toothed belt drive.

- The toothed belt is 5mm wider than the toothed belt used in the base engine. Higher forces can be transmitted as it has a larger surface area.

- A hydraulic toothed belt tensioner keeps the belt evenly tensioned in different load states.

- Some of the teeth on the crankshaft timing belt gear have a larger gap clearance in order to reduce toothed belt wear.



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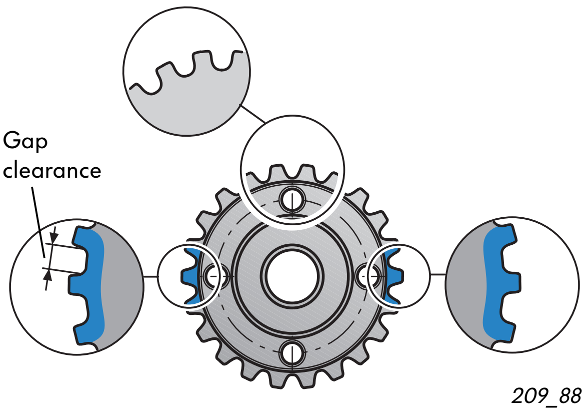
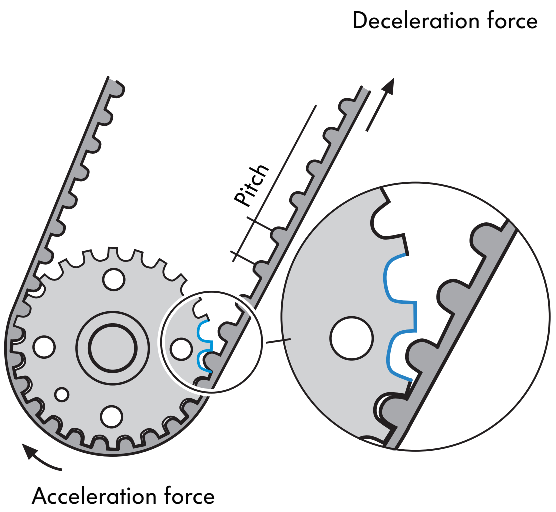
To relieve the load on the toothed belt during the injection cycle, the toothed belt of the crankshaft has two pairs of teeth which have a larger gap clearance than the other teeth.



209_88

This is how it works:

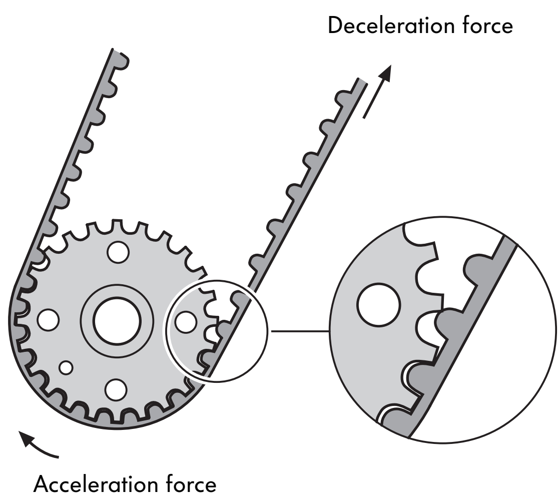
During the injection cycle, the high pumping forces exert a heavy load on the toothed belt. The camshaft gear is slowed down by the pumping forces. At the same time, the combustion process which now begins speeds up the crankshaft timing belt gear. The toothed belt is stretched and the pitch is temporarily increased as a result.



209_91

On account of the firing order, this process occurs periodically. As a result, the same teeth on the timing belt gear are in mesh every time. The teeth have a larger gap clearance at these points in order to compensate for the change in tooth pitch and thus reduce toothed belt wear.

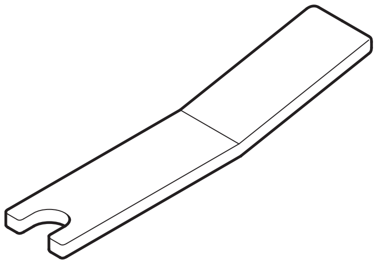
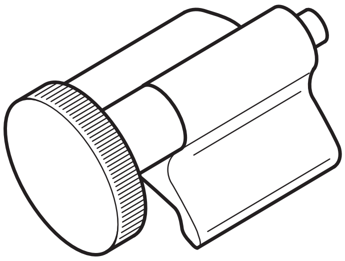
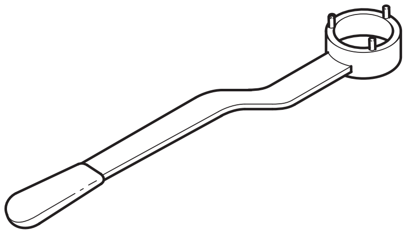
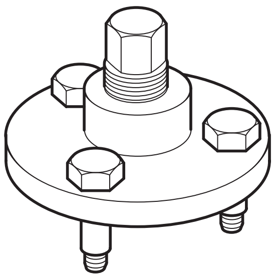
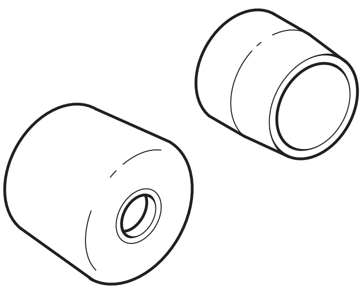
On a crankshaft timing belt with a uniform tooth gap clearance, the teeth of the toothed belt abut against the tooth edges of the timing belt gear when the toothed belt is placed under heavy strain by high pumping forces.
The upshot of this is that the toothed belt wears quickly and has a short service life.



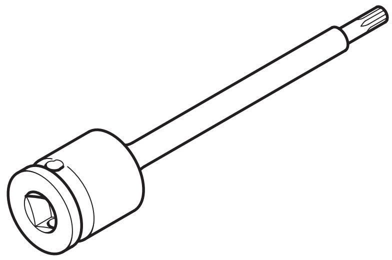
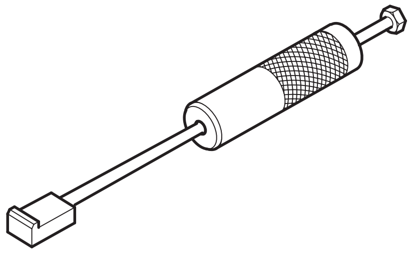
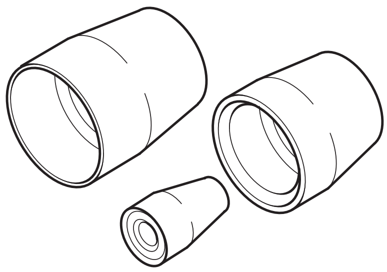
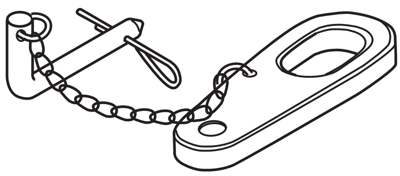
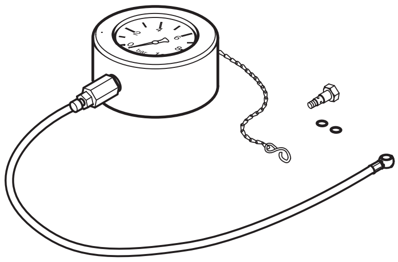
209_92

Service

Special tools

Designation	Tool	Use
T 10008 marking plate		For fixing the hydraulic toothed belt tensioner in place when installing and removing the toothed belt.
T 10050 crankshaft stop		For fixing the crankshaft in place at the crankshaft gear when adjusting the port timing.
T 10051 counter-holder for camshaft gear		For installing the camshaft gear
T 10052 puller for camshaft gear		For detaching the camshaft gear from the tapered end of the camshaft
T 10053 assembly fixture for crankshaft sealing ring		Guide sleeve and compression sleeve for installing the crankshaft sealing ring

Special tools

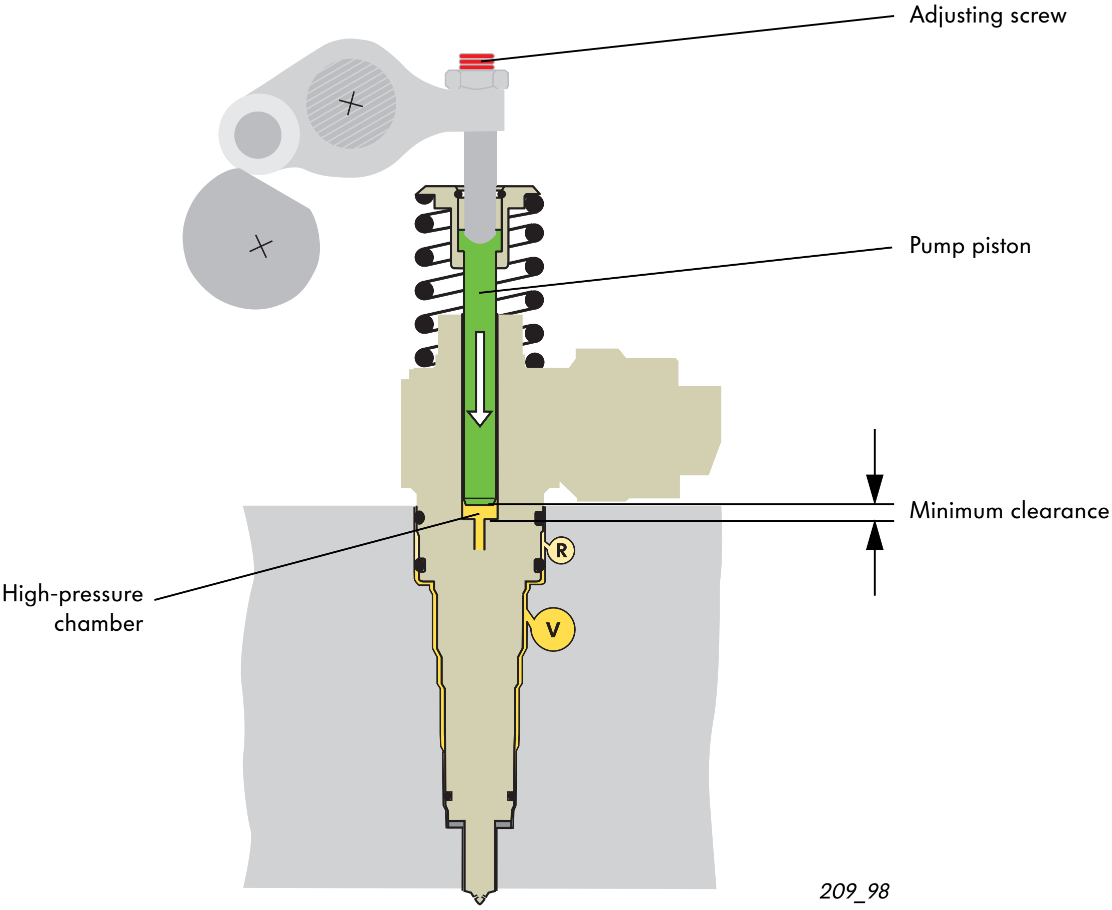
Designation	Tool	Use
T 10054 socket insert		For fitting the fastening bolt of the pump injector clamping block.
T 10055 puller for pump injector element		For pulling the pump injector out of the cylinder head.
T 10056 assembly sleeves for O-rings		For installing the O-rings of the pump injectors.
T 10059 shackle		For installing and removing the engine in the Passat. The engine is moved into the installation position using this shackle in combination with lifting gear 2024A.
V.A.S. 5187 pressure gauge		For gauging, the fuel pressure is the supply line to the fuel pump.

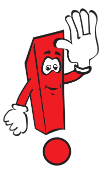
209_90a-k

Repair notes

After installing the pump injector, the minimum clearance between the base of the high-pressure chamber and the pump piston must be adjusted in the lowest position at the adjusting screw of the pump injector.

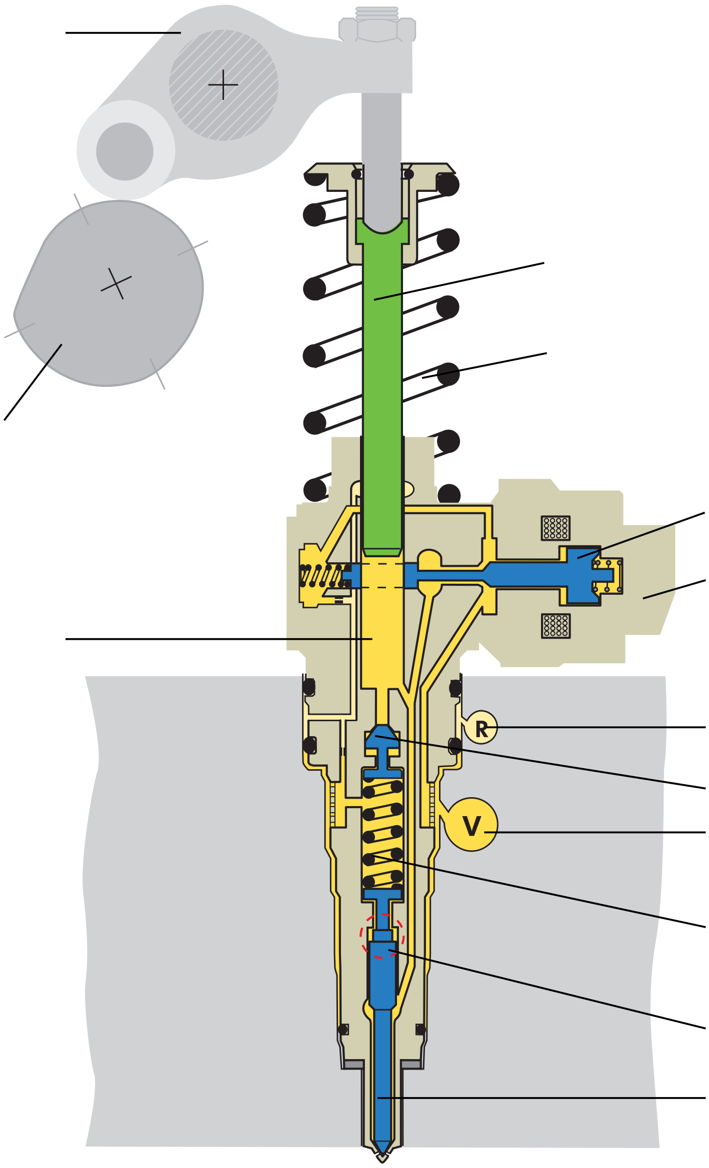
This adjustment prevents the pump piston knocking against the base of the high-pressure chamber due to heat expansion.





You will find a description of the adjustment procedure in the Workshop Manual.

1. Identify the components



209_23

2. Which of the following statements is true?

☐ a. An engine with a pump injection system is more efficient and cleaner than an engine with a distributor injection pump.

☐ b. The high combustion efficiency of the pump injector engine is the result of the high injection pressure.

☐ c. Each cylinder in the engine has a single pump injector.

Test your knowledge

3. What component ends the pre-injection cycle?

☐ a. Injector solenoid valve

☐ b. Retraction piston

☐ c. Injector needle damper

4. What is the task of the fuel cooling system?

☐ a. It prevents the fuel tank and the fuel level sender from being damaged by excessively hot fuel.

☐ b. The cooled fuel lowers the combustion temperature and thus reduces nitrogen oxide emissions.

☐ c. Cooling the fuel allows it to be evenly distributed to the cylinders.

5. Hall sender G40 . . .

☐ a. . . . determines the engine speed.

☐ b. . . . recognises the individual cylinders.

☐ c. . . . recognises cylinder 1 only

6. What makes quick engine starting possible?

☐ a. During the starting cycle, all injector solenoid valves are activated simultaneously by the engine control unit.

☐ b. The engine control unit evaluates the signals supplied by the Hall sender and engine speed sender. This enables the engine control unit to recognise the position of the crankshaft in relation to the cylinder at an early stage and activate the correct injector solenoid valve to start the injection cycle.

☐ c. The injection cycle is started as soon as the engine control unit detects cylinder 1 through the signal supplied by the Hall sender.

Notes

Solutions:

1. For a list of components, refer to page 8
2. a, b, c
3. b
4. a
5. b
6. b

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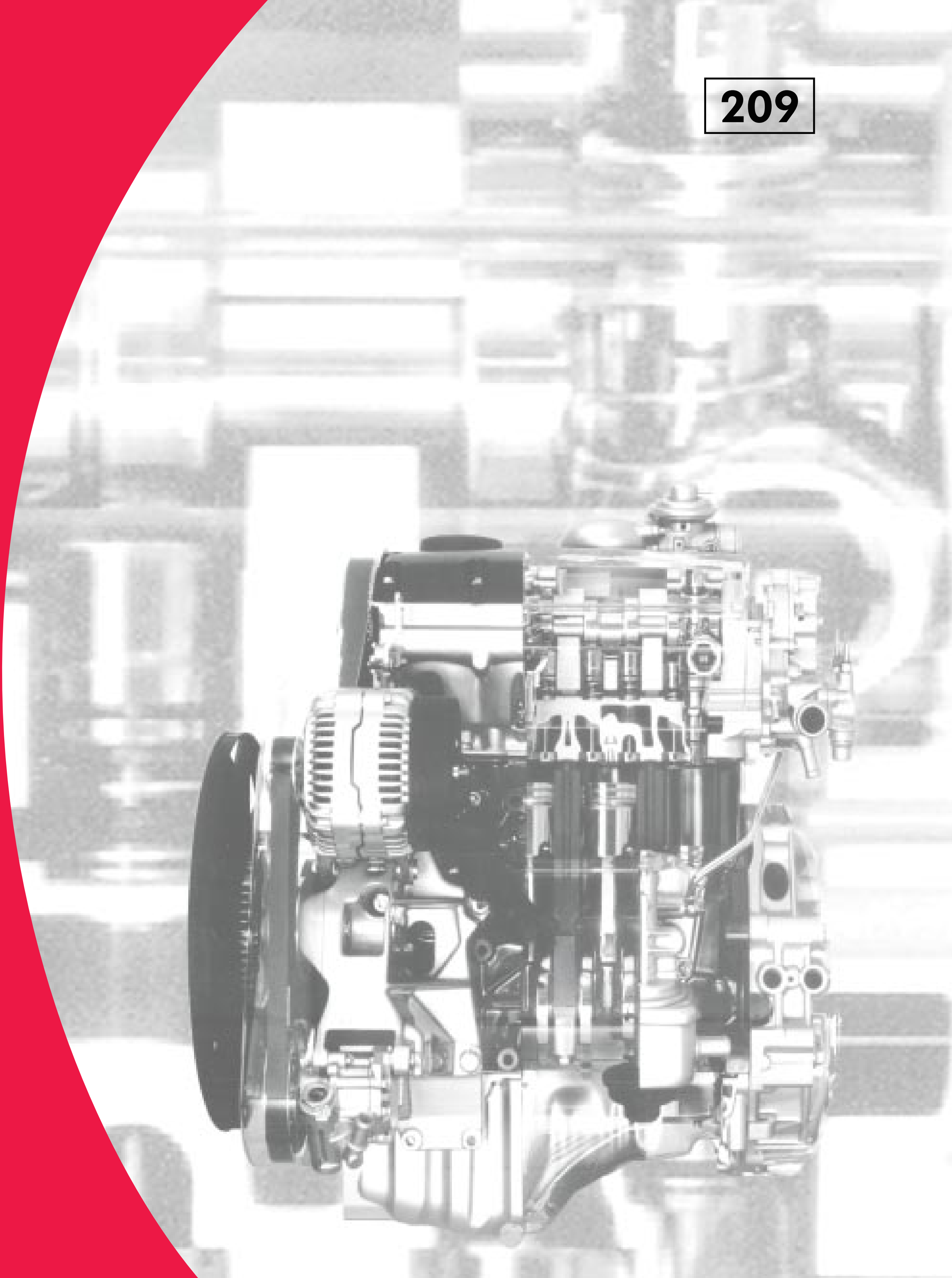

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