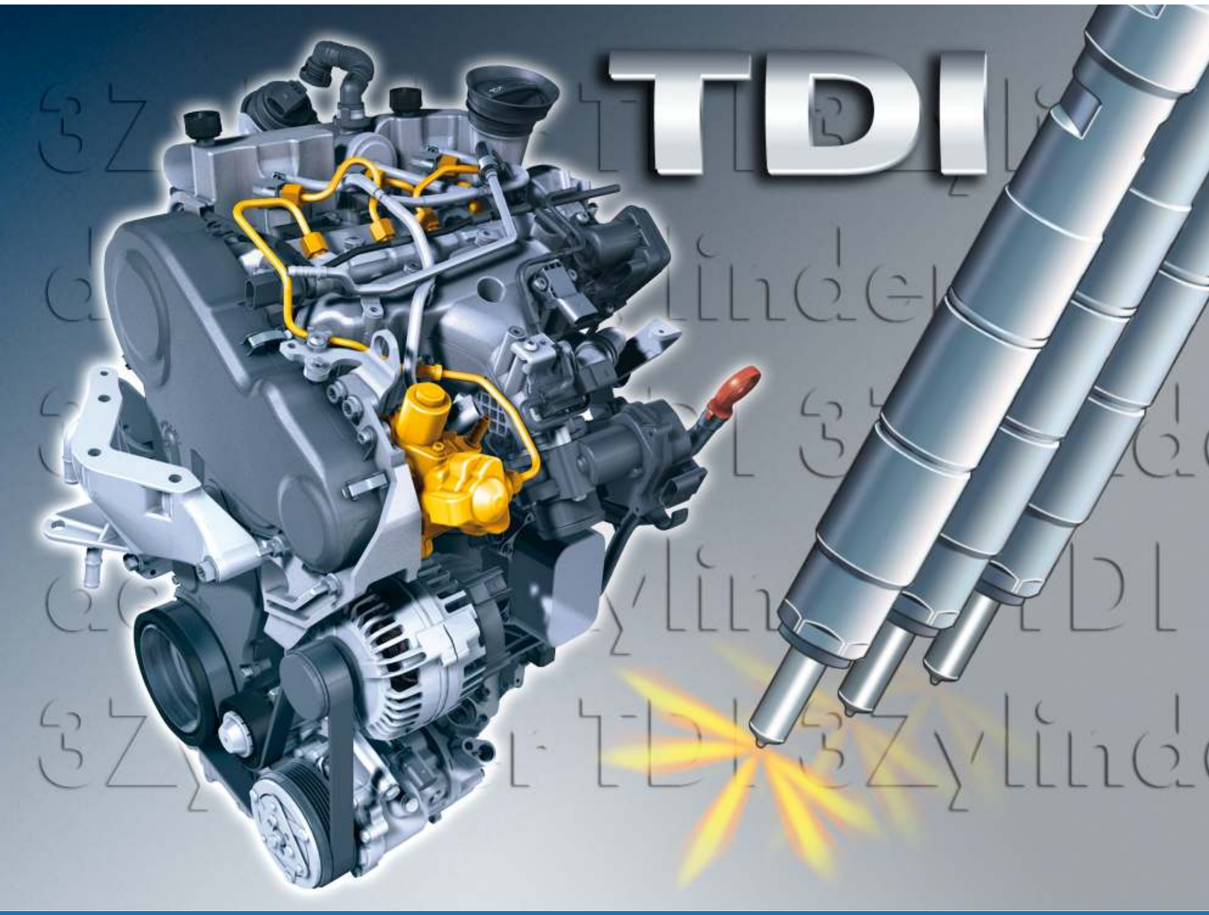
Service Training

Self-study Programme 465

The 1.2l 3-cylinder TDI engine with common rail fuel injection system

Design and Function



S465_002

Reduced to the maximum

The 1.2l TDI engine with common rail injection system has joined the new generation of efficient, economic and dynamic diesel engines from Volkswagen.

This new three-cylinder diesel engine was developed on the basis of the 1.6l TDI four-cylinder diesel engine introduced in early 2009 and replaces the successful 1.4l TDI engine with unit injector system.

The new 1.2l TDI engine not only meets the growing demand for dynamics and comfort in an ideal way, it also boasts extremely low consumption and pollutant emissions.

Thanks to this engine, the Polo Blue Motion scores top marks with a minimal fuel consumption of 3.3l/100km and CO_2 emissions of 87g/km.

The self-study programme portrays the design and function of new developments.
The contents will not be updated.

For current testing, adjustment and repair instructions, refer to the relevant service literature.

Important Note

Contents

Introduction

1.2l 55kW TDI engine

A new 3-cylinder engine has been developed in the form of the 1.2l 55kW TDI engine.
It is based on the 1.6l TDI engine introduced at the beginning of 2009.

This engine design is a prime example of “down-sizing”.
Down-sizing refers to a reduction in the displacement of an engine without changing the output or the torque. The displacement can be reduced by reducing the displacement of each cylinder, reducing the number of cylinders or a combination of both. This reduces the weight and the internal friction of the engine and thus the fuel consumption.

In the case of the 1.2l TDI CR engine, the number of cylinders has been reduced from 4 to 3 compared with the 1.6l TDI CR engine while the cylinder displacement is unchanged.

In addition to the weight and friction-reducing measures, this engine is equipped with a new common rail injection system that contributes to reducing harmful emissions by using a high maximum injection pressure and precise control.

Thanks to the new 1.2l 55kW TDI engine and further measures like aerodynamic modifications to the front, sides, floor and rear end, the start/stop system and low rolling resistance tires mounted on alloy rims, the Polo Blue Motion scores top marks with a low fuel consumption of 3.3l/100km and CO_2 emissions of 87g/km.

S465_025

The design and function of the 1.6l TDI engine are described in self-study programme no. 442 “1.6ltr. TDI engine with common rail injection system”.

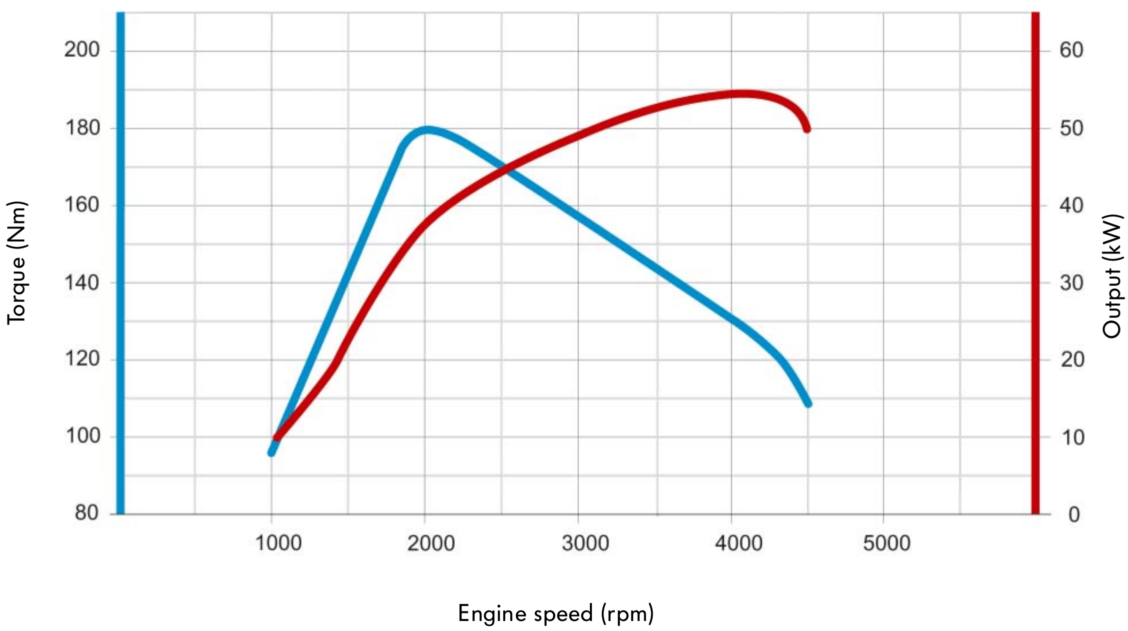
Technical features

- Common rail fuel injection system with solenoid valve-controlled injectors
- Adjustable turbocharger
- Exhaust gas recirculation module consisting of an exhaust gas recirculation valve and switchable exhaust gas recirculation cooler
- Oxidising catalytic converter
- Balancer shaft module

Technical data

Engine code	CFWA
Type	3-cylinder in-line engine
Displacement	1,199cm^3
Bore	79.5mm
Stroke	80.5mm
Valves per cylinder	4
Compression ratio	16.5 : 1
Maximum output	55kW at 4,200rpm
Maximum torque	180Nm at 2,000rpm
Engine management	Delphi DCM 3.7
Fuel	Diesel complying with DIN EN590
Exhaust gas treatment	Exhaust gas recirculation, oxidising catalytic converter, diesel particulate filter
Emissions standard	EU5

Output and torque graph



S465_024

Engine Components

Cylinder block

The cylinder block of the 1.2l TDI engine is basically the same as the cylinder block of the 1.6l TDI engine with common rail injection system.
Since the 1.2l TDI engine has one less cylinder, the cylinder block is accordingly shorter and lighter.

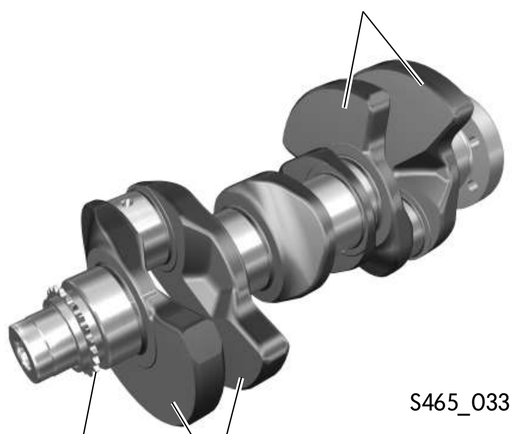
The cylinder diameter is 79.5mm and the stroke is 80.5mm. This almost square stroke/bore ratio leads to low friction losses on the cylinder liners.
This measure is used to reduce the internal friction of the engine and contributes to the low fuel consumption.

S465_031

Crankshaft

The rotating moments of inertia of the engine are balanced by the counterweights on the crank webs of cylinders 1 and 3.

The two outer crank webs (weights) have larger dimensions than the two inner crank webs. The larger lever arm of the outer weights in relation to the centre of gravity of the crankshaft distributes the mass perfectly to balance the forces.



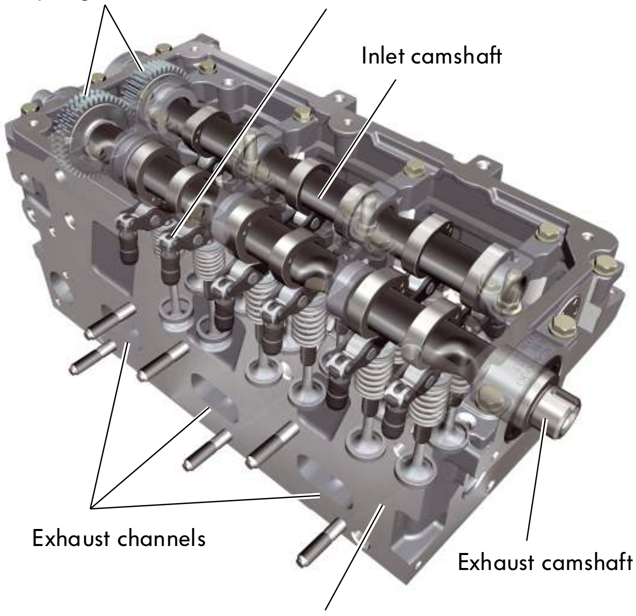
S465_033

Cylinder head

The cylinder head of the 1.2l TDI engine is made from cast aluminium and has two inlet and two exhaust valves on each cylinder. The valves are arranged according to the principle of cross-flow.

The camshafts are driven by the crankshaft via a toothed belt and the exhaust camshaft gear wheel. The intake and exhaust camshafts are linked via meshed spur gears with integrated backlash compensation.

The valves are actuated by low-friction roller rocker fingers with hydraulic valve play compensation.

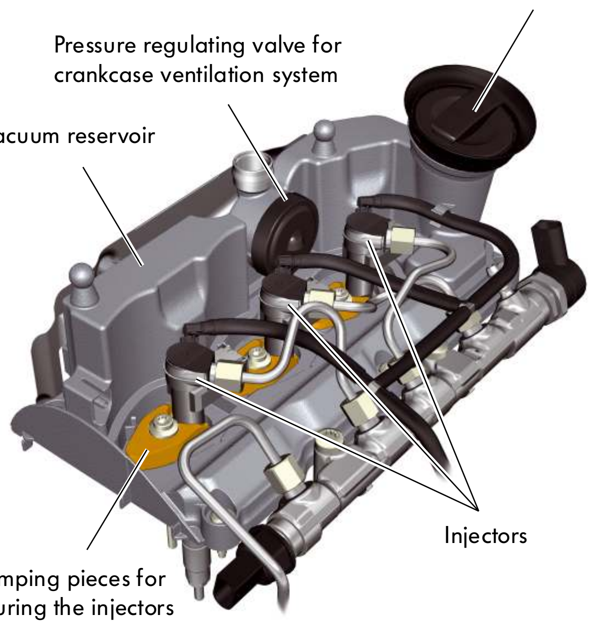


S465_032

Cylinder head cover

The oil filler neck, the crankcase ventilation system, the pressure accumulator for the engine vacuum system and the seals for the injectors have been integrated into the cylinder head cover.

The injectors are secured in the cylinder head with the aid of clamping pieces.



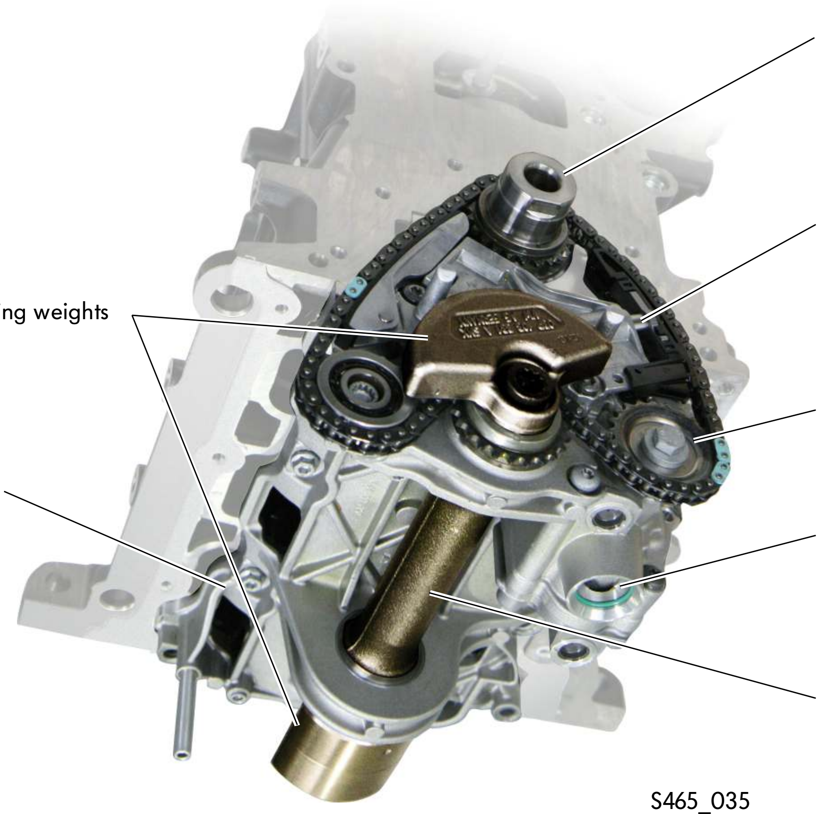
S465_034

Balancer shaft module

A balancer shaft is located in the engine crankshaft drive. It has the task of reducing vibrations and thus making the engine run quieter.

The upwards and downwards movements of the pistons and connecting rods as well as the rotary movement of the crankshaft produce forces that cause vibrations. These vibrations are transferred to the vehicle body via the engine mounts. The balancer shaft acts against the forces of the pistons, connecting rods and crankshaft to reduce the vibrations.

The balancer shaft has been integrated into a balancer shaft module together with the ladder frame and the oil pump. It is driven by the crankshaft via a chain. The balancer shaft rotates at engine speed in the opposite direction to the engine.

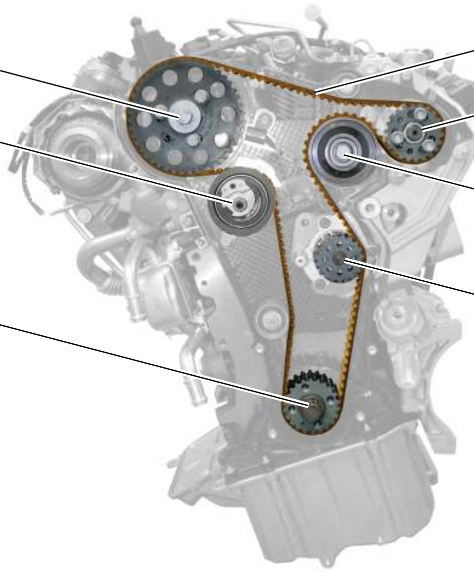


S465_035

The crankshaft and balancer shaft must be in the correct position relative to each other to effectively balance the moments of inertia.
Observe the information in the workshop manual when installing the balancer shaft.

Toothed belt drive

The exhaust camshaft, the high-pressure pump for the common rail system and the coolant pump are driven by the toothed belt.



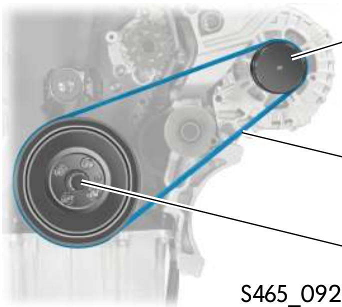
S465_004

Ancillary component drive

Depending on the vehicle equipment, there are two variants for driving the engine ancillary components.

Poly V-belt drive for vehicles without air-conditioning compressor

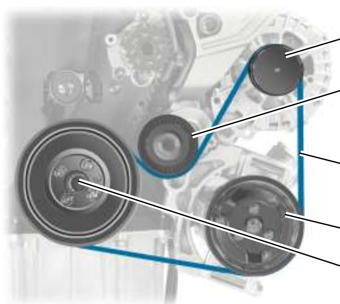
Only the alternator is driven via a flexible, stretchable poly V-belt, called a flexi belt. A belt tensioner is not required due to use of the flexi belt.



S465_092

Poly V-belt drive for vehicles with air-conditioning compressor

The ancillary components are driven by a conventional poly V-belt in this case. The poly V-belt is tensioned by a spring-loaded belt tensioner.

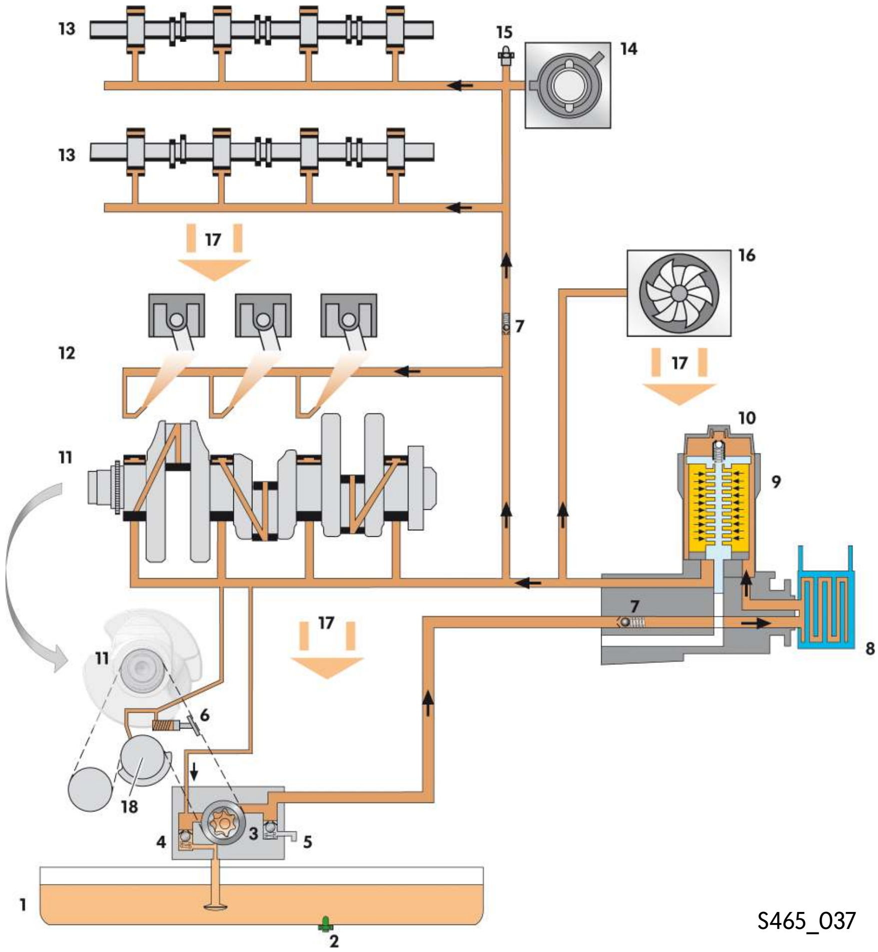


S465_036

Follow the instructions in the workshop manual when fitting the poly V-belt.

Oil system

A duocentric oil pump generates the oil pressure required to lubricate the engine. It has been integrated into the balancer shaft module and is driven by the crankshaft via a chain.
The pressure relief valve is a safety valve. It prevents engine components being damaged by excessive oil pressure, for example, at low outside temperatures and at high engine speeds.
The oil pressure regulating valve regulates the engine oil pressure. It opens as soon as the oil pressure has reached the maximum permitted value. The filter bypass valve opens if the oil filter becomes clogged up to ensure lubrication of the engine.



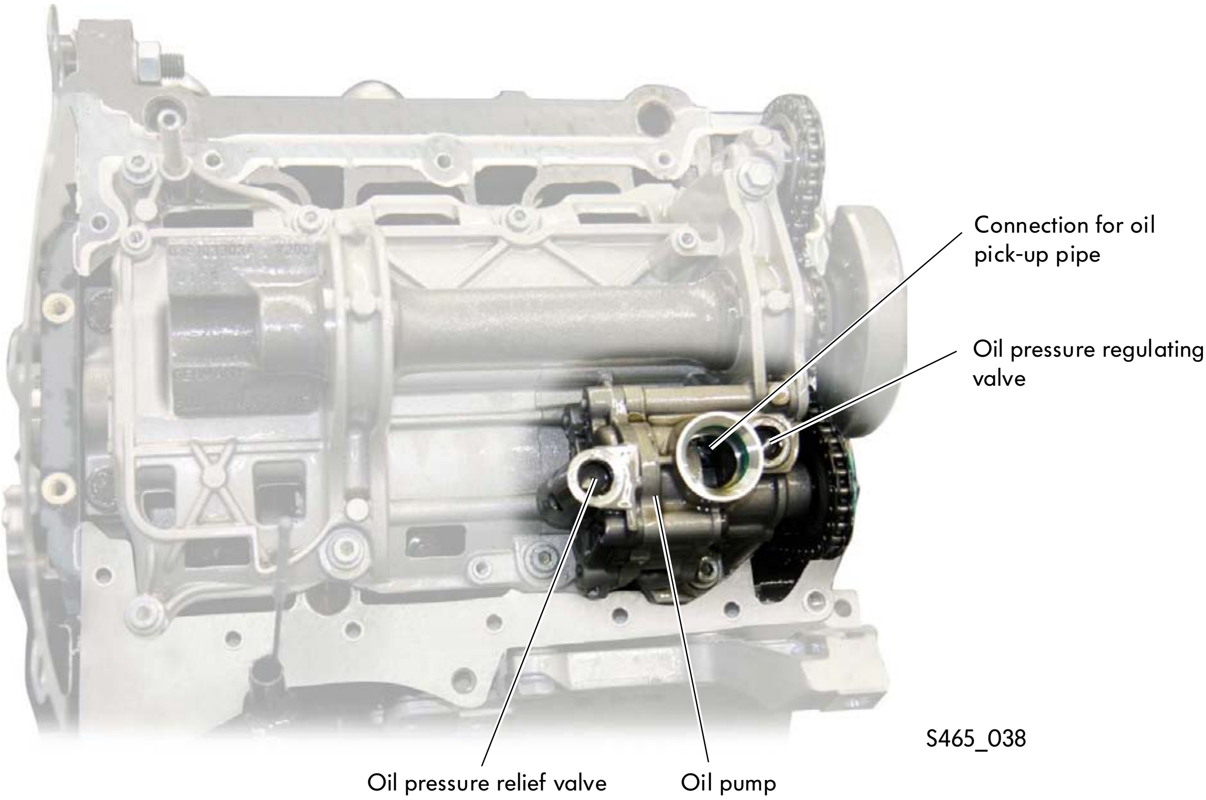
S465_037

Legend

1 - Oil sump
2 - Oil level and oil temperature sender G266
3 - Oil pump
4 - Oil pressure regulating valve
5 - Pressure relief valve
6 - Hydraulic chain tensioner
7 - Oil non-return valve
8 - Oil cooler
9 - Oil filter
10 - Filter bypass valve
11 - Crankshaft
12 - Jets for piston cooling
13 - Camshafts
14 - Vacuum pump
15 - Oil pressure switch F1
16 - Turbocharger
17 - Oil return
18 - Balancer shaft

Oil pump

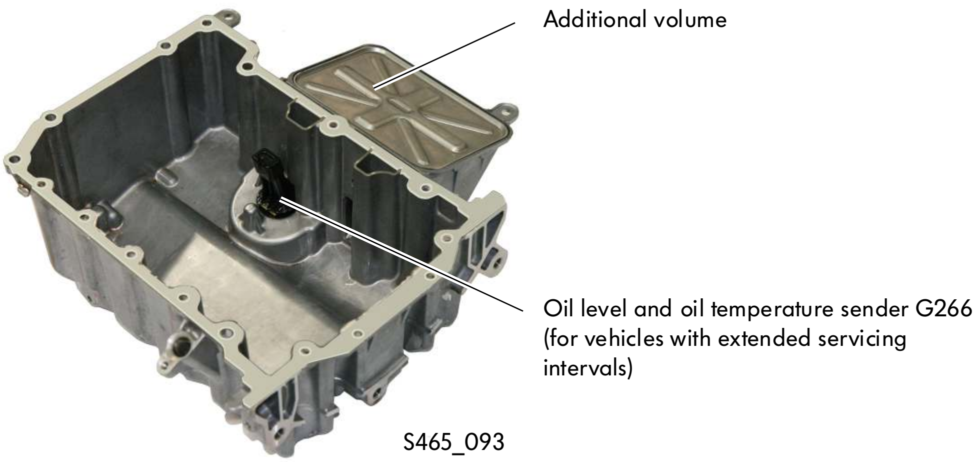
The duocentric oil pump has been integrated into the balancer shaft ladder frame and is driven by the crankshaft via a chain. The chain is tensioned by a hydraulic chain tensioner.



S465_038

Oil sump

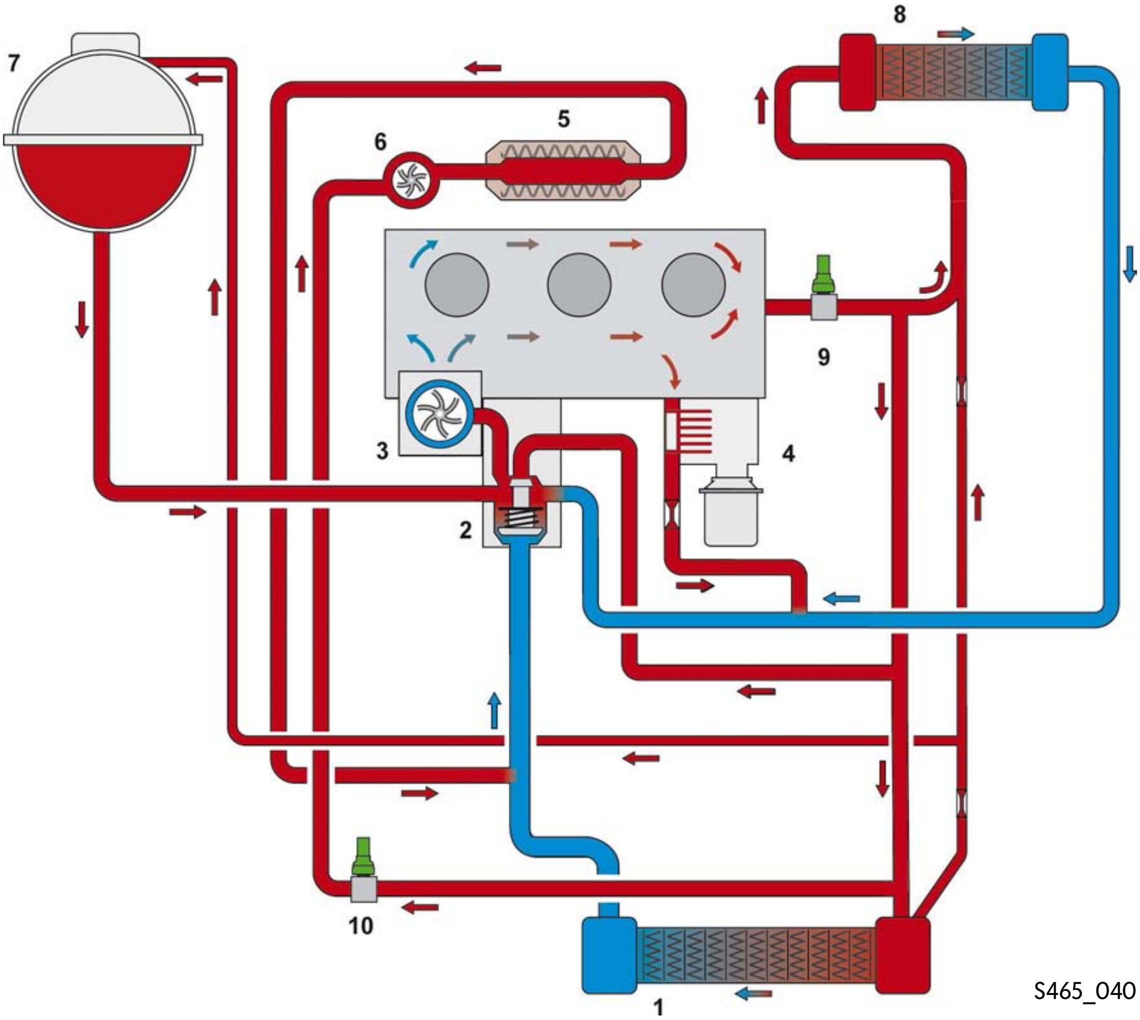
The oil sump has been expanded with additional volume to accommodate the quantity of oil required by the engine.



S465_093

Coolant circuit

The coolant is circulated around the coolant circuit by a mechanical coolant pump. The pump is driven by the toothed belt. The system is controlled by an expansion-type thermostat.



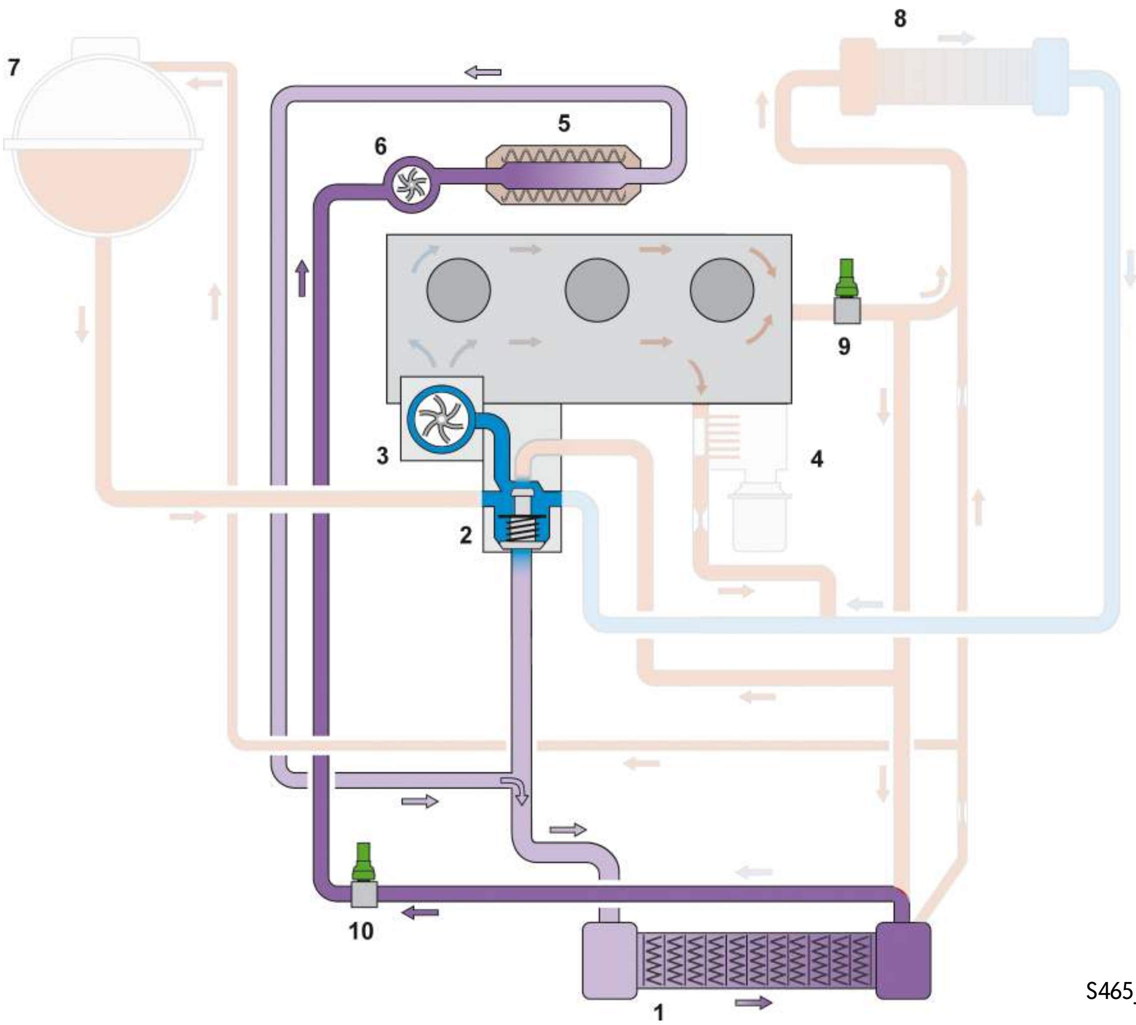
S465_040

Legend

1 - Radiator for engine coolant circuit
2 - Thermostat
3 - Coolant pump
4 - Oil cooler
5 - Cooler for exhaust gas recirculation
6 - Coolant circulation pump 2 V178
7 - Expansion tank
8 - Heat exchanger for heating system
9 - Coolant temperature sender G62
10 - Radiator outlet coolant temperature sender G83

Low-temperature exhaust gas recirculation

The engine is equipped with a low-temperature exhaust gas recirculation system to reduce the NO_x emissions.



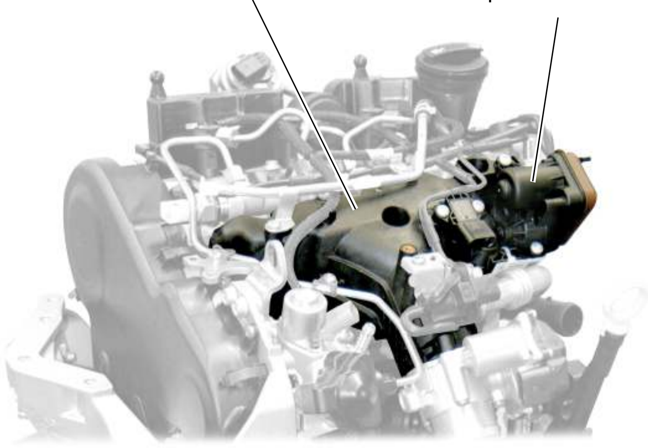
S465_041

Function

When the thermostat is closed, the exhaust gas recirculation cooler is supplied with cold coolant straight from the engine radiator. A larger quantity of exhaust gas can then be recirculated due to the resulting greater drop in temperature. This allows the combustion temperatures and consequently the nitrogen oxide emissions to be further reduced during the engine warm-up phase.
The electrical auxiliary water pump (coolant circulation pump 2 V178) is activated by the engine control unit and runs constantly once the engine has been started.

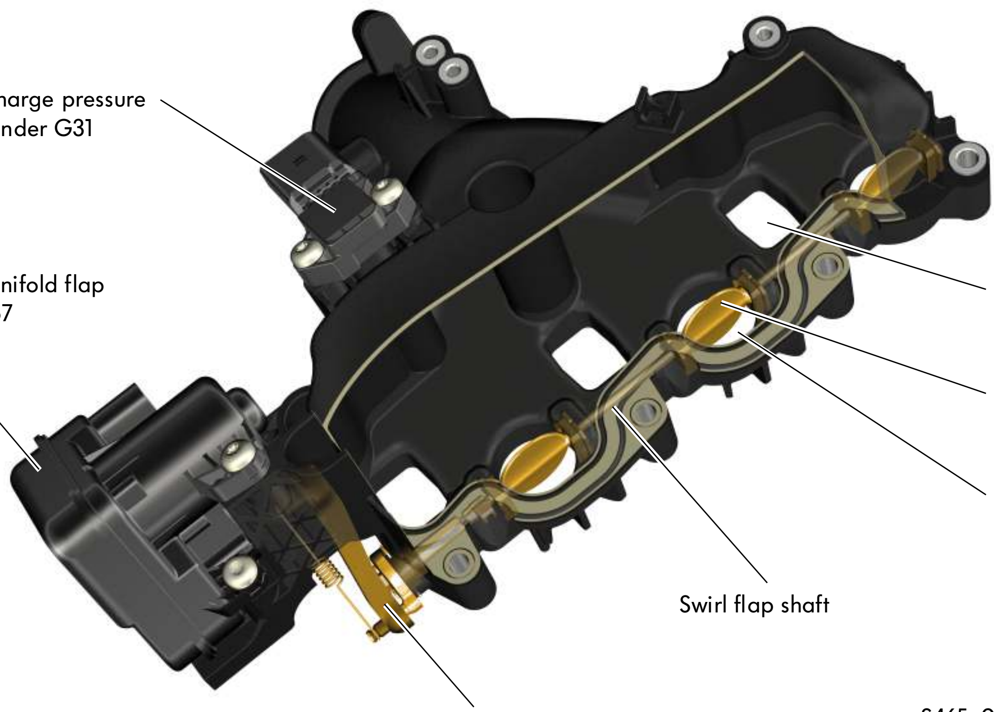
Intake manifold with swirl flaps

Continuously variable swirl flaps are fitted in the intake manifold.
The swirl of the intake air is adjusted via the position of the swirl flaps in relation to the engine speed and load.
The swirl flaps are fixed on the swirl flap shaft and are moved by the intake manifold flap motor via a push rod. The positioning motor is actuated by the engine control unit for this purpose.
The intake manifold flap potentiometer G336 has been integrated into the intake manifold flap motor V157. It informs the engine control unit about the current position of the swirl flaps.



S465_043

Design

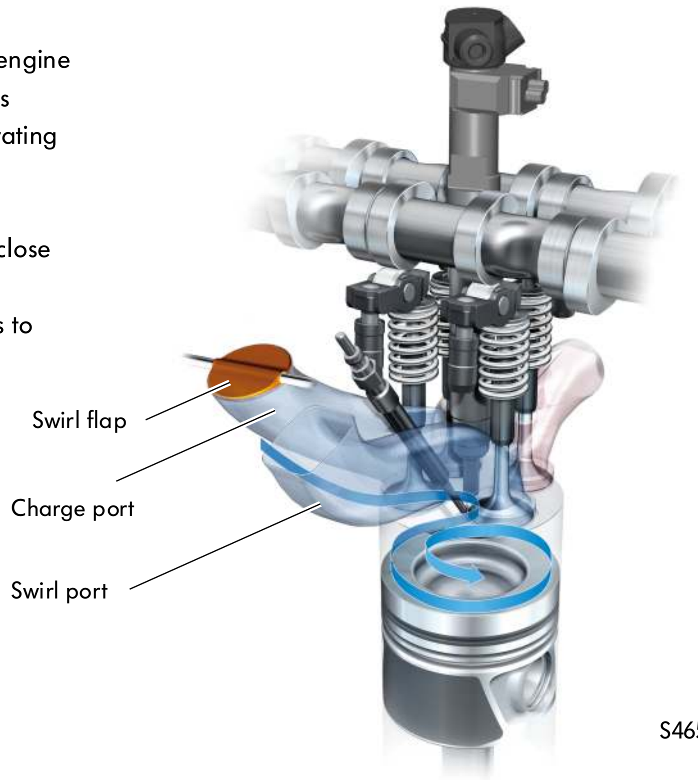


S465_044

Function of the swirl flaps

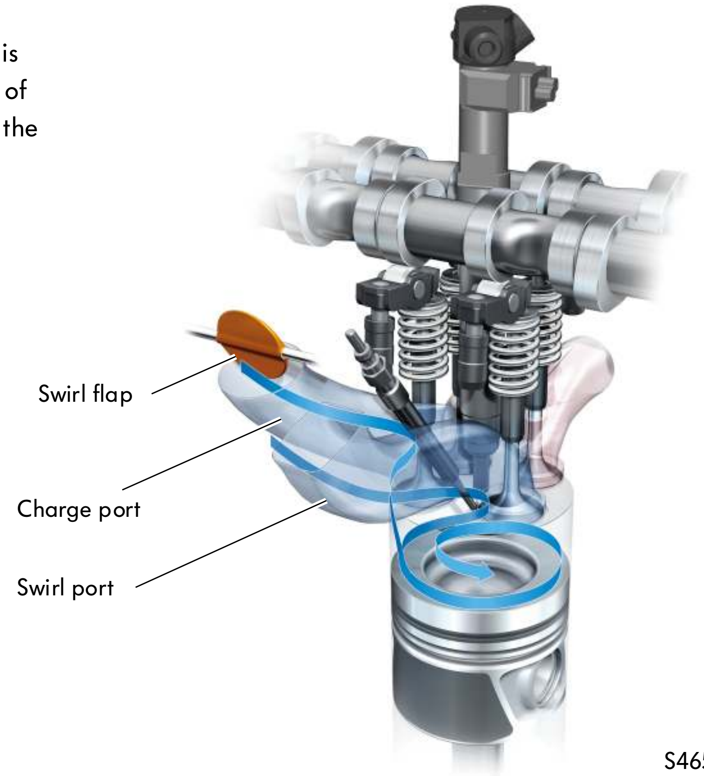
While the engine is running, the swirl flaps are constantly adjusted according to the load and engine speed. As a result, the optimum air movement is present in the combustion chamber for all operating ranges.

In the lower partial load range, the swirl flaps close between halfway and fully.
This causes a high level of swirling, which leads to good mixture formation.



S465_045

The swirl flaps are fully open when the engine is started, at idle and at full throttle. Good filling of the combustion chamber is achieved thanks to the increased air throughput.



S465_046

Fuel system
Schematic overview

1 - Fuel system pressurisation pump G6

The fuel system pressurisation pump constantly delivers fuel to the supply line at a pressure of approx. 6 bar.

2 - Pressure regulator for fuel supply line

The pressure control valve regulates the pressure in the fuel supply line to approx. 5 bar and sends the extra fuel back to the fuel tank.

3 - Fuel filter

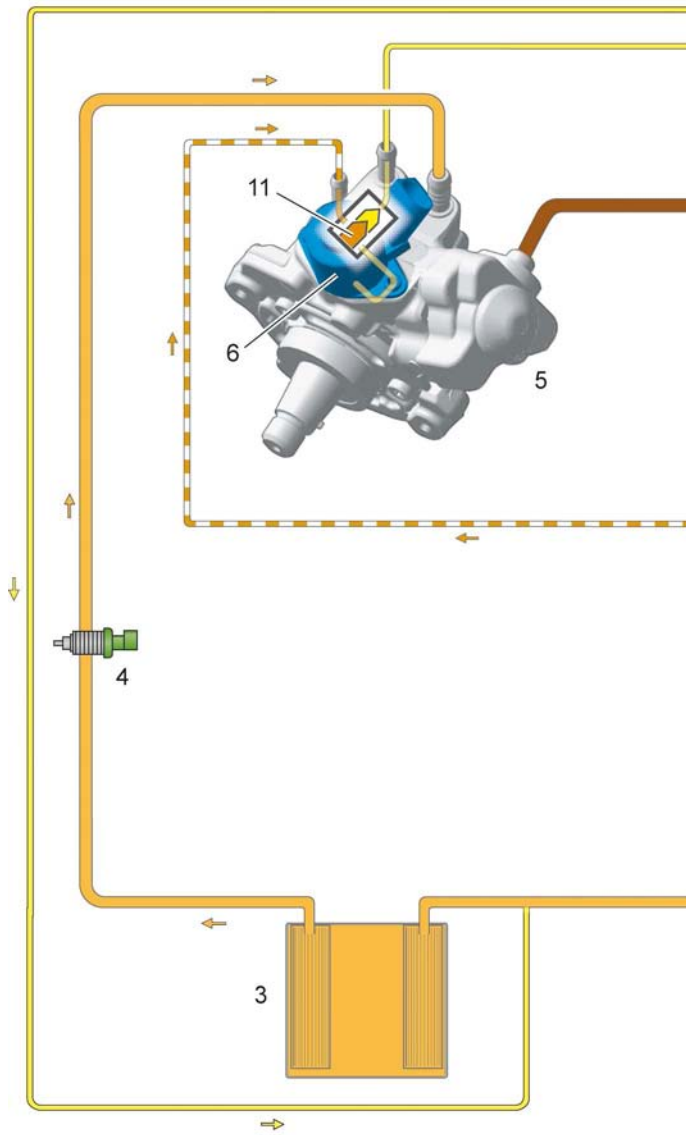
The fuel filter keeps impurities in the diesel fuel away from the components of the injection system. The high-precision components, for example, the high-pressure pump and the injectors, can be damaged or their function impaired by even the most minute particles of dirt.

4 - Fuel temperature sender G81

The fuel temperature sender measures the current fuel temperature.

5 - High-pressure pump

The high-pressure pump generates the high fuel pressure required for injection.



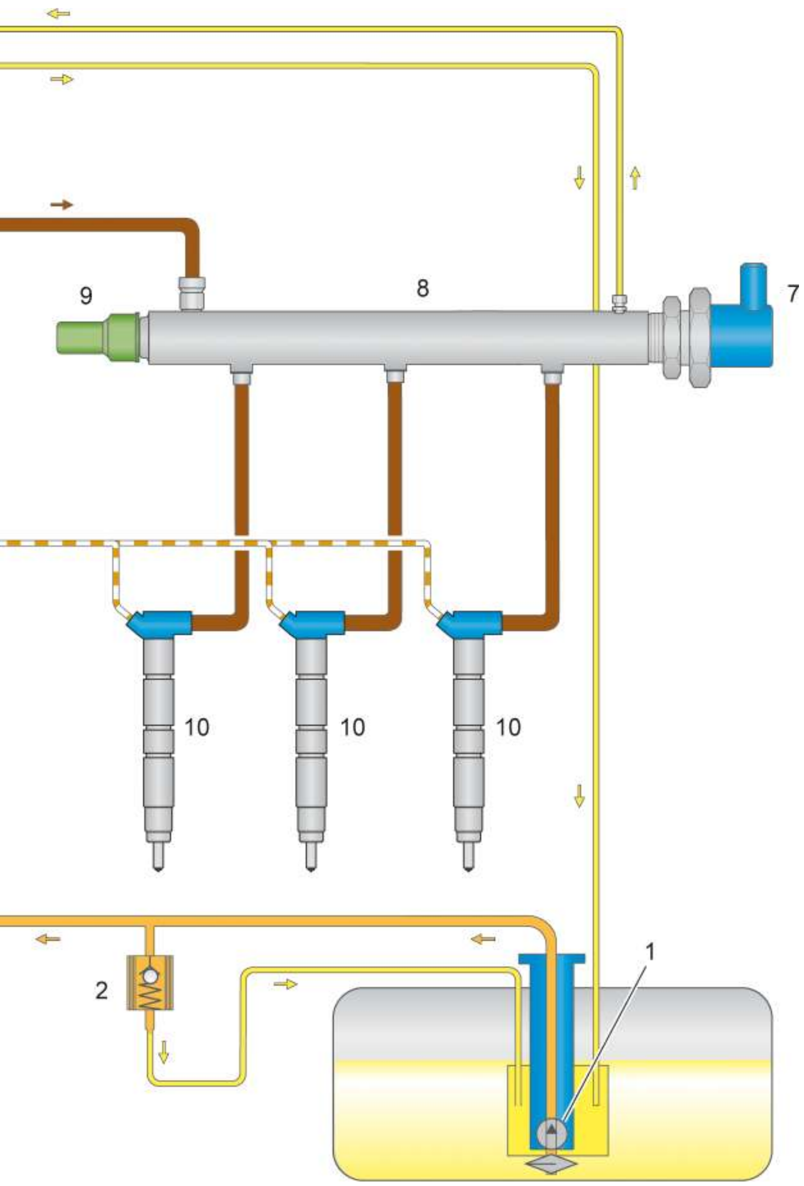
Colour code/legend

High pressure 230 – 1,800 bar

Supply pressure 5 bar

Return pressure 0.3 bar

Return pressure from the injectors (negative pressure) –0.1 bar to –0.5 bar



S465_047

6 - Fuel metering valve N290

The fuel metering valve regulates the quantity of fuel needed to generate the high pressure as required.

7 - Fuel pressure regulating valve N276

The fuel pressure regulating valve opens below a certain fuel temperature to pre-heat the fuel filter.

8 - High-pressure accumulator (rail)

The high-pressure accumulator stores the fuel required for injection into all cylinders under high pressure.

9 - Fuel pressure sender G247

The fuel pressure sender measures the current fuel pressure in the high-pressure area.

10 - Injectors N30, N31, N32

The injectors inject the fuel into the combustion chambers.

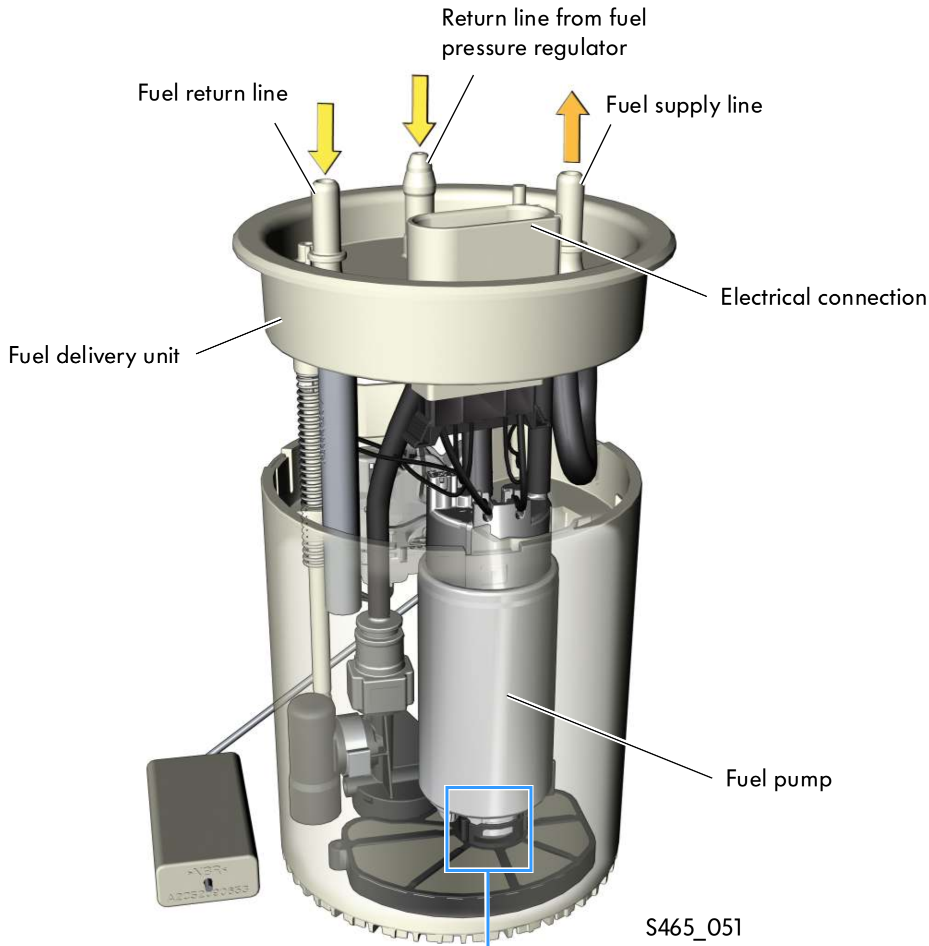
11 - Venturi nozzle

The venturi nozzle in the high-pressure pump generates the negative pressure in the fuel return of the injectors.

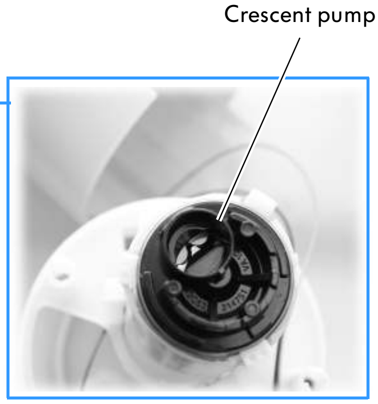
Engine Components

Fuel system pressurisation pump G6

The fuel system pressurisation pump is an electrically driven crescent pump. It has been integrated into the fuel delivery unit and generates a pressure of approx. 6 bar in the fuel system supply line. This ensures that the high-pressure pump is supplied with sufficient fuel in all operating states. The fuel pump is activated by the engine control unit via a relay when the engine is started.



S465_051



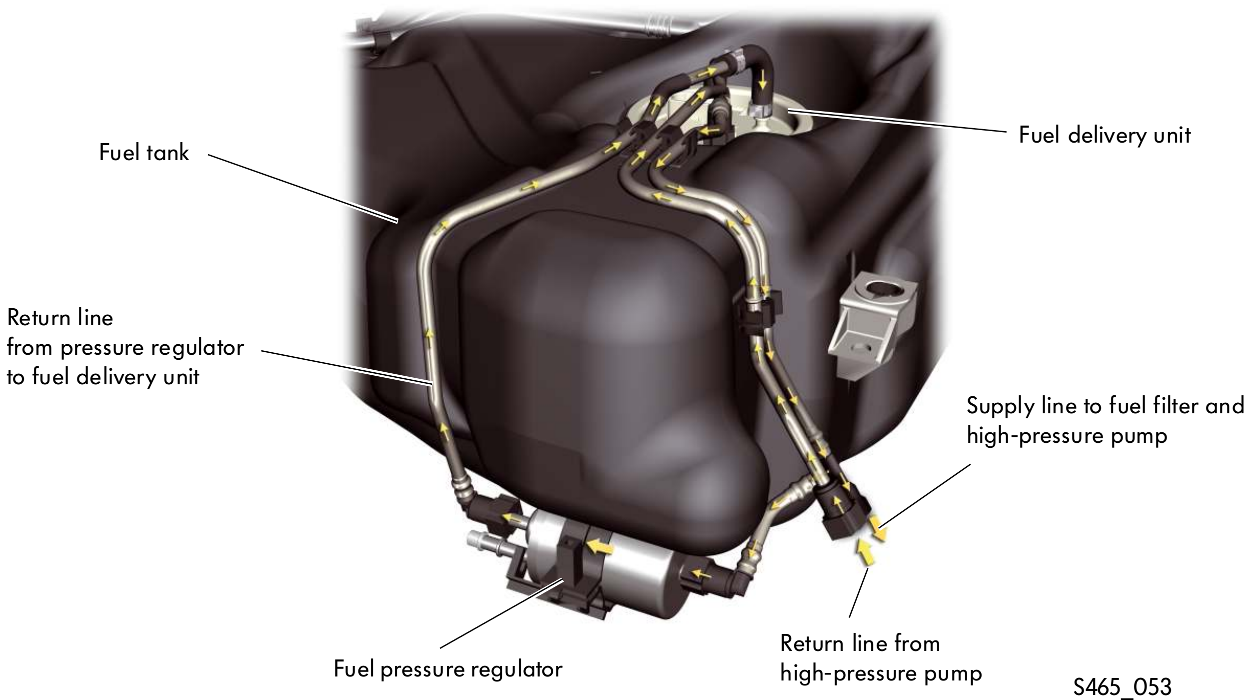
S465_052

Effects upon failure

The engine will not run if the fuel system pressurisation pump fails.

Fuel pressure regulator

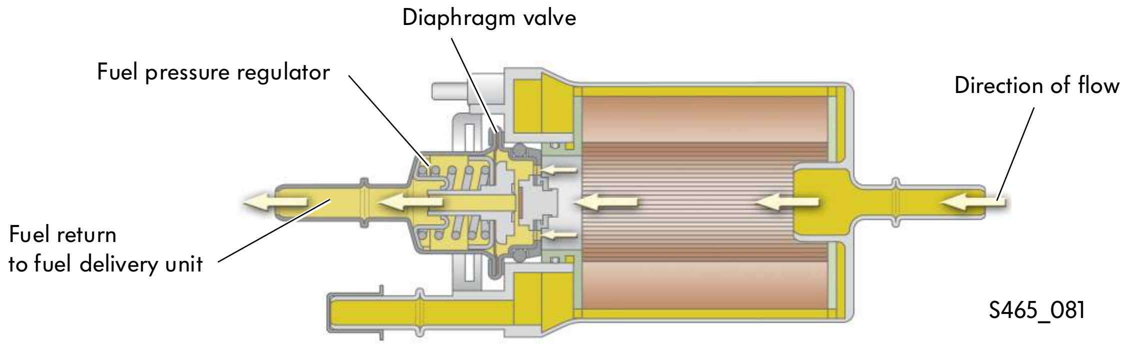
The fuel pressure regulator is located near the vehicle floor on the right-hand side of the fuel tank.
The fuel pressure regulator reduces the fuel pressure generated by the fuel system pressurisation pump in the fuel supply line to approx. 5 bar. This results in a constant pressure level in the fuel supply line.



S465_053

How it works

The fuel delivered by the fuel system pressurisation pump reaches the fuel pressure regulator via a branch channel. A spring-loaded diaphragm valve in the chamber of the fuel pressure regulator sets the fuel pressure at approx. 5 bar. If the pressure rises above 5 bar, the diaphragm valve opens and the fuel flows back into the fuel delivery module.



S465_081

The fuel pressure regulator is also called additional fuel filter in the repair literature. The filter in the chamber does not have any function, however. This component only has the task of regulating the fuel pressure in the low-pressure system.

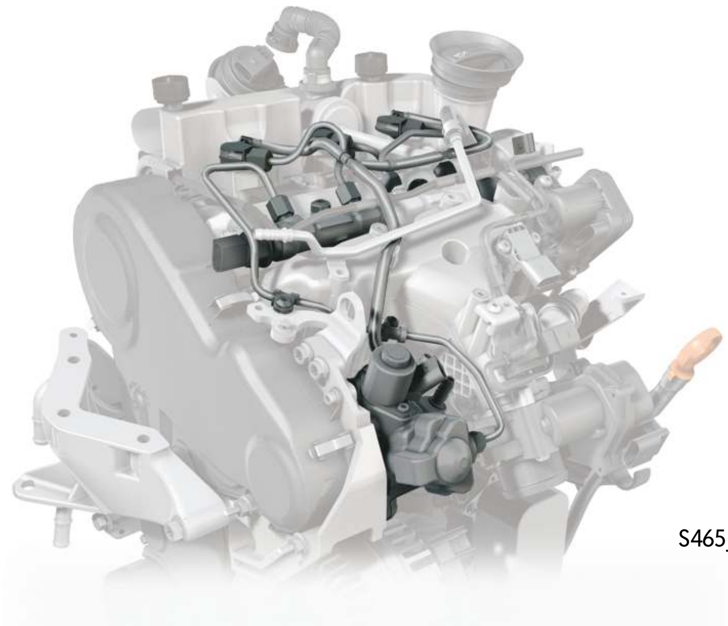
Common rail fuel injection system

The common rail fuel injection system for the 1.2l TDI engine was developed by Volkswagen and DELPHI.

The pressure generation and the fuel injection are separate in the common rail injection system. The high-pressure pump generates the high fuel pressure required for injection.

This fuel pressure is stored in the high-pressure accumulator (rail) and is supplied to the injectors via short injector pipes. A venturi nozzle integrated in the high-pressure pump creates a negative pressure in the fuel return of the injectors that allows a high injector operating speed.

The common rail fuel injection system is regulated by the Delphi DCM 3.7 engine management system.



S465_086

The common rail fuel injection system provides many options for adapting the injection pressure and the injection process to the engine operating mode.

The characteristics of the common rail injection system are:

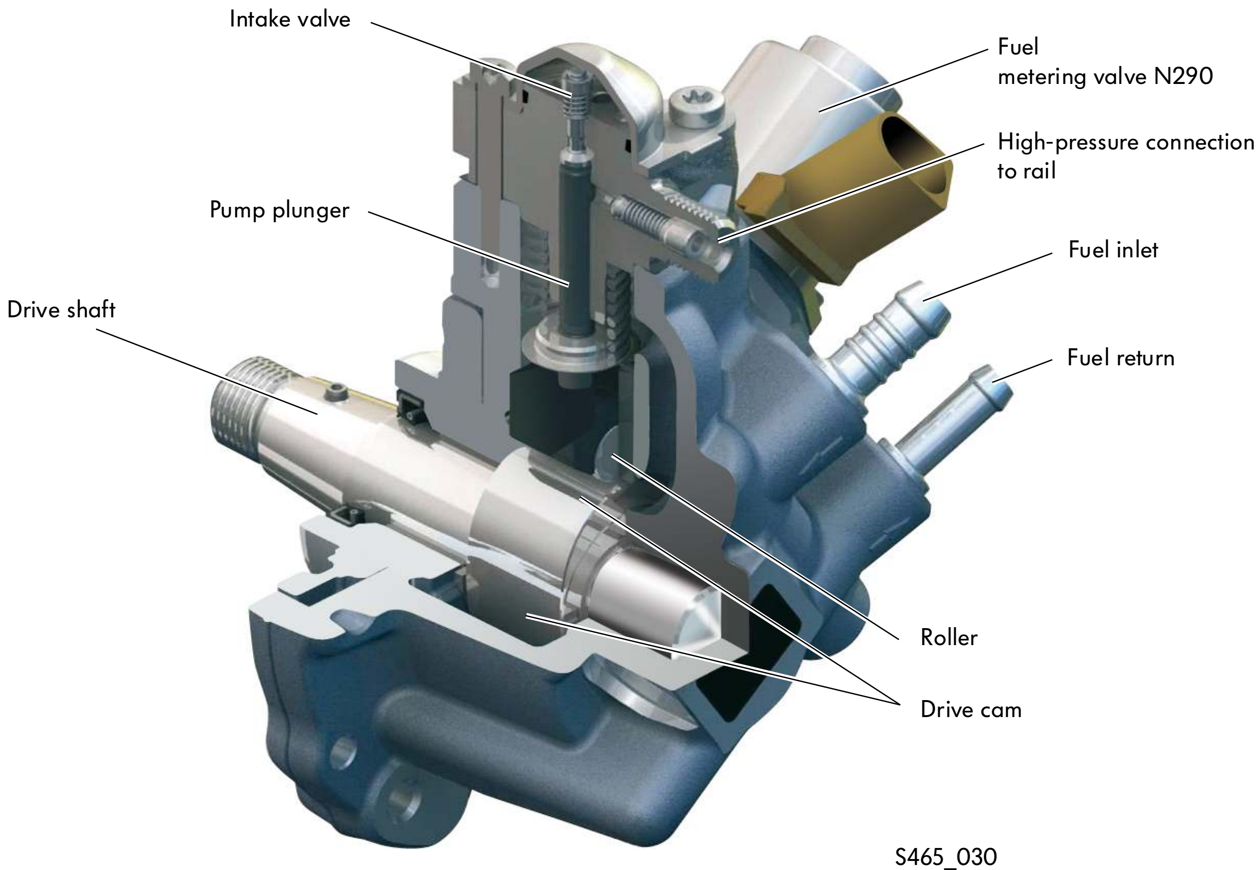
- A high injection pressure up to a maximum of 1,800 bar enables good mixture formation.
- The injection pressure can be selected almost infinitely and can be adapted to the current engine operating status.
- The injection process can be made flexible with several pilot injections for quiet combustion and several secondary injections for regeneration of the diesel particulate filter.

High-pressure pump

The high-pressure pump is a single-plunger pump. It is driven at engine speed by the crankshaft via the toothed belt.
The high-pressure pump has the task of generating the high fuel pressure of up to 1,800 bar, which is required for fuel injection. The two cams on the drive shaft are offset by 180°. A roller, which runs on the cam of the drive shaft, ensures low-friction power transmission to the pump plunger.
The high-pressure pump housing contains the fuel metering valve N290 for regulating the fuel flow in the high-pressure area and a venturi nozzle for generating negative pressure in the fuel return of the injectors.

S465_072

Design of high-pressure pump



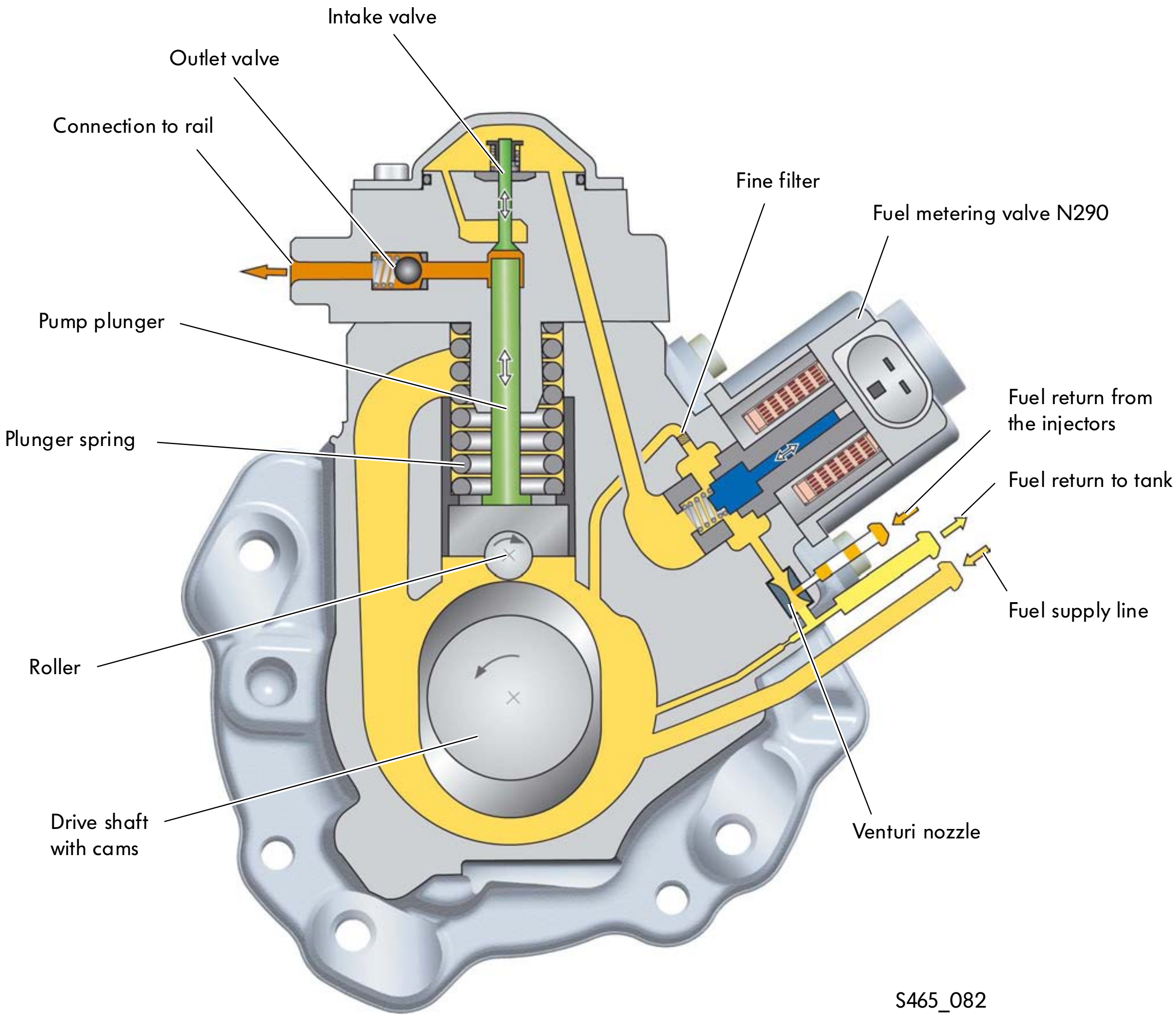
S465_030

Design of high-pressure pump – schematic

The high-pressure pump is supplied with sufficient fuel by the fuel system pressurisation pump in all operating modes of the engine.

The fuel reaches the high-pressure area of the rail system via the fuel metering valve.

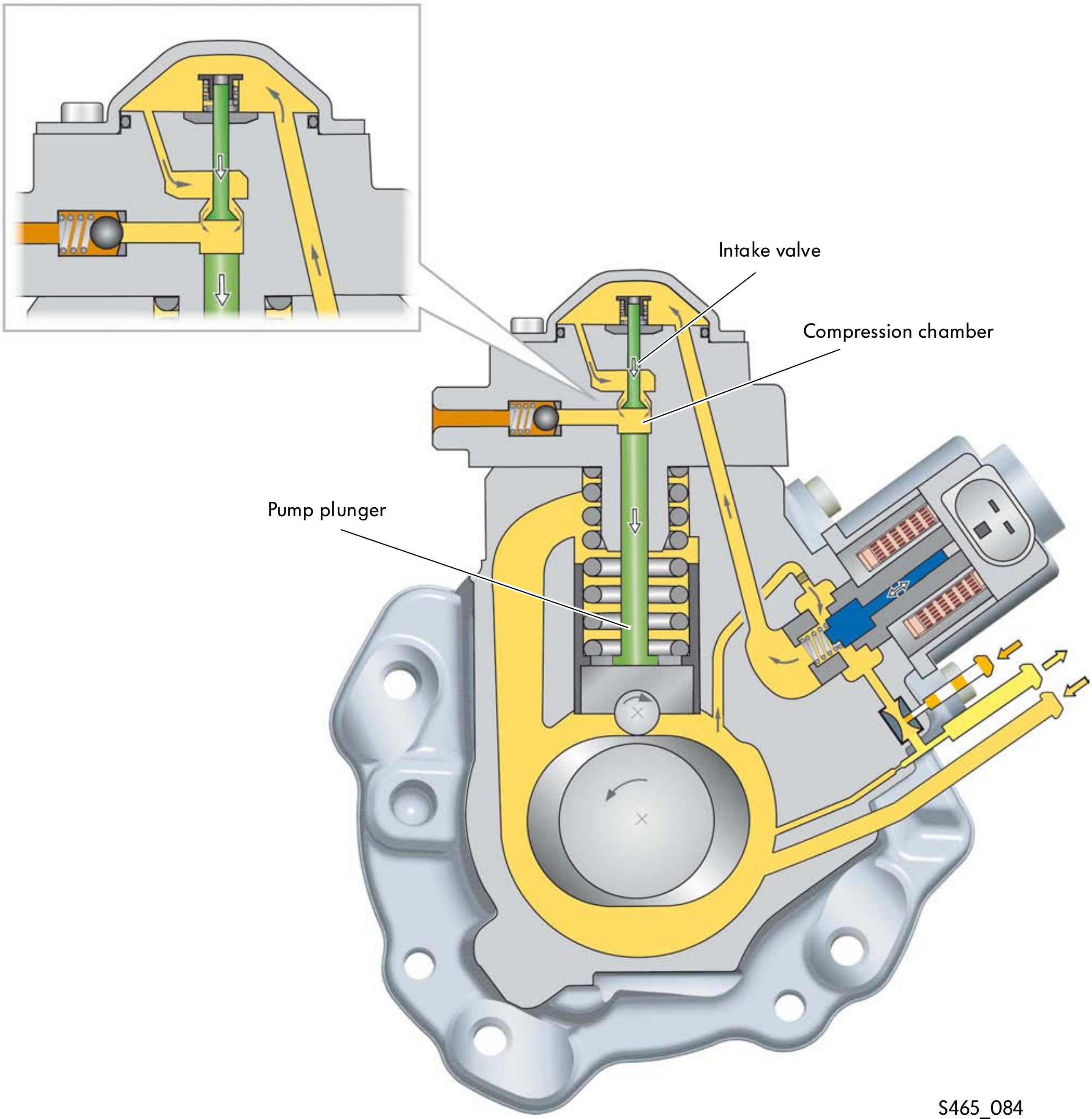
The pump plunger is moved upwards and downwards by the cams on the drive shaft.



S465_082

Suction stroke

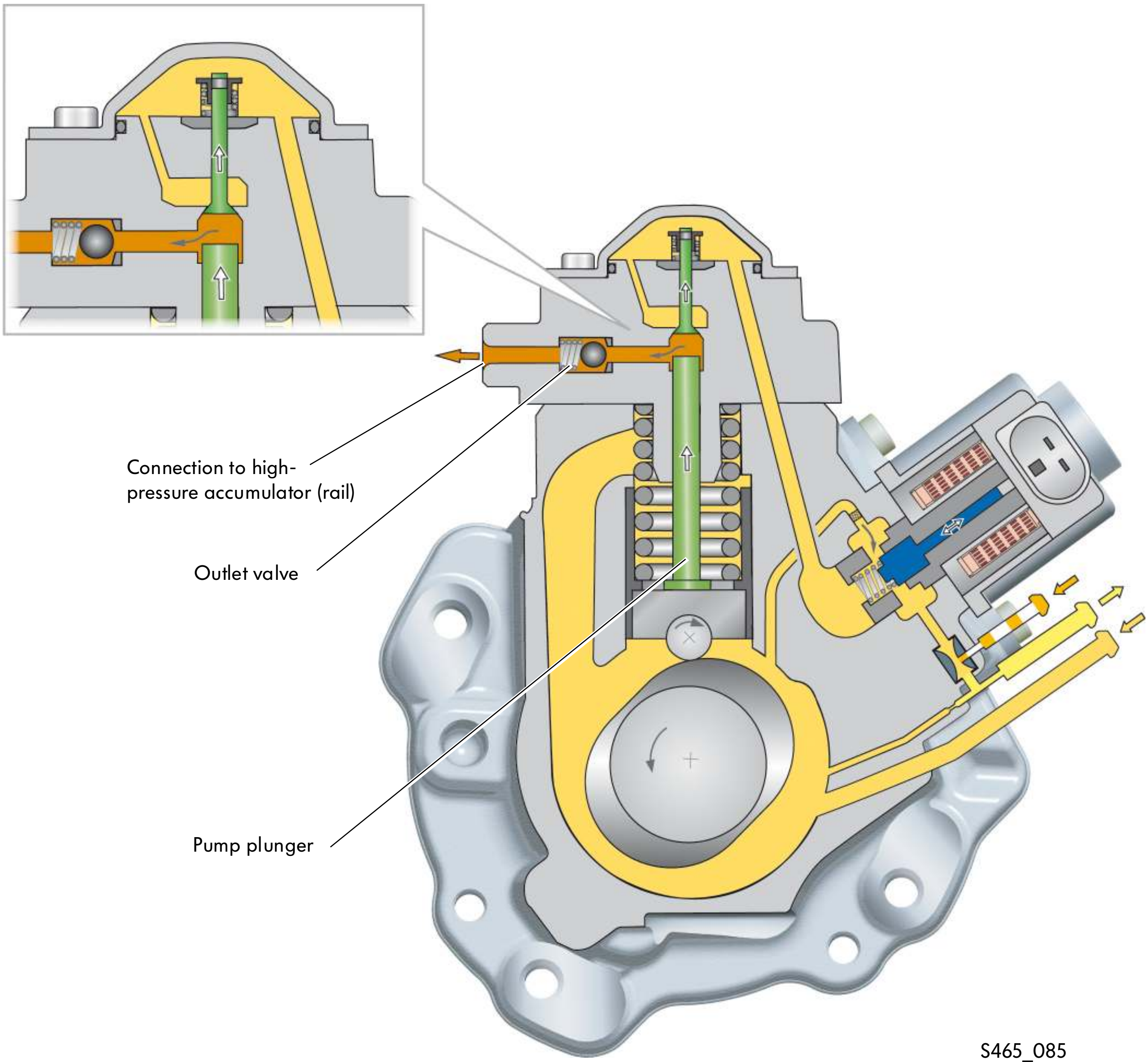
The downwards movement of the pump plunger increases the volume of the compression chamber. This causes a difference in pressure between the fuel in the high-pressure pump and the fuel in the compression chamber. The intake valve opens and fuel flows into the compression chamber.



S465_084

Delivery stroke

The pressure in the compression chamber increases and the intake valve closes when the pump plunger starts to move upwards. As soon as the fuel pressure in the compression chamber exceeds the pressure in the high-pressure area, the outlet valve (non-return valve) opens and the fuel enters the high-pressure accumulator (rail).



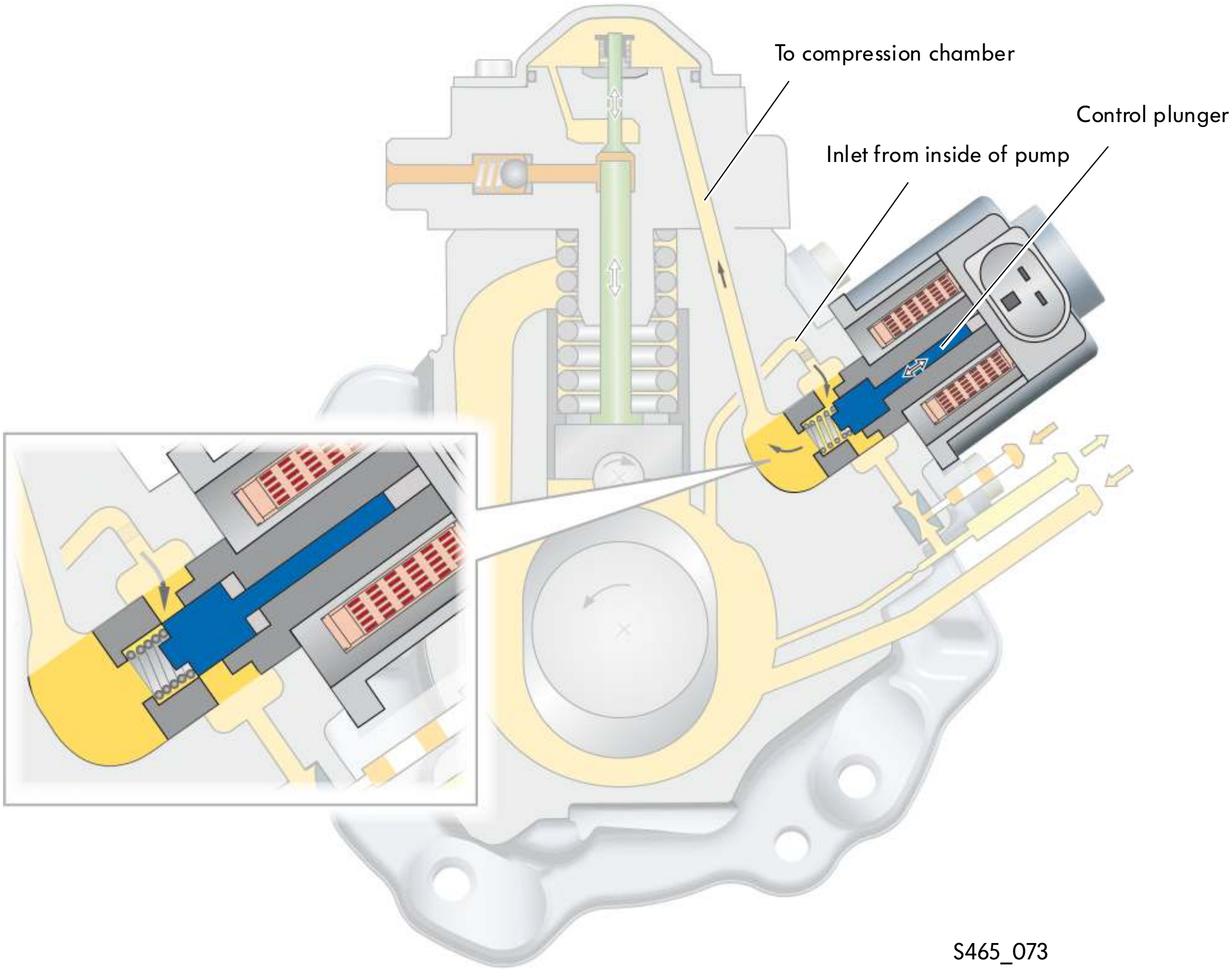
Fuel metering valve N290

The fuel metering valve has been integrated into the high-pressure pump. It ensures that the fuel pressure is regulated as required in the high-pressure area. The fuel metering valve regulates the fuel quantity that is required to produce high pressure. The advantage of this is that the high-pressure pump only has to generate the pressure that is required for the current operating situation. This reduces the power consumption of the high-pressure pump and avoids unnecessary fuel heating.

Function

When no current is supplied, the fuel metering valve is open. To reduce the quantity flowing to the compression chamber, the valve is actuated by the engine control unit with a pulse-width modulated (PWM) signal.

The fuel metering valve is pulsed closed by the PWM signal. The position of the control plunger and therefore the quantity of fuel flowing into the compression chamber of the high-pressure pump varies in relation to the pulse control factor.



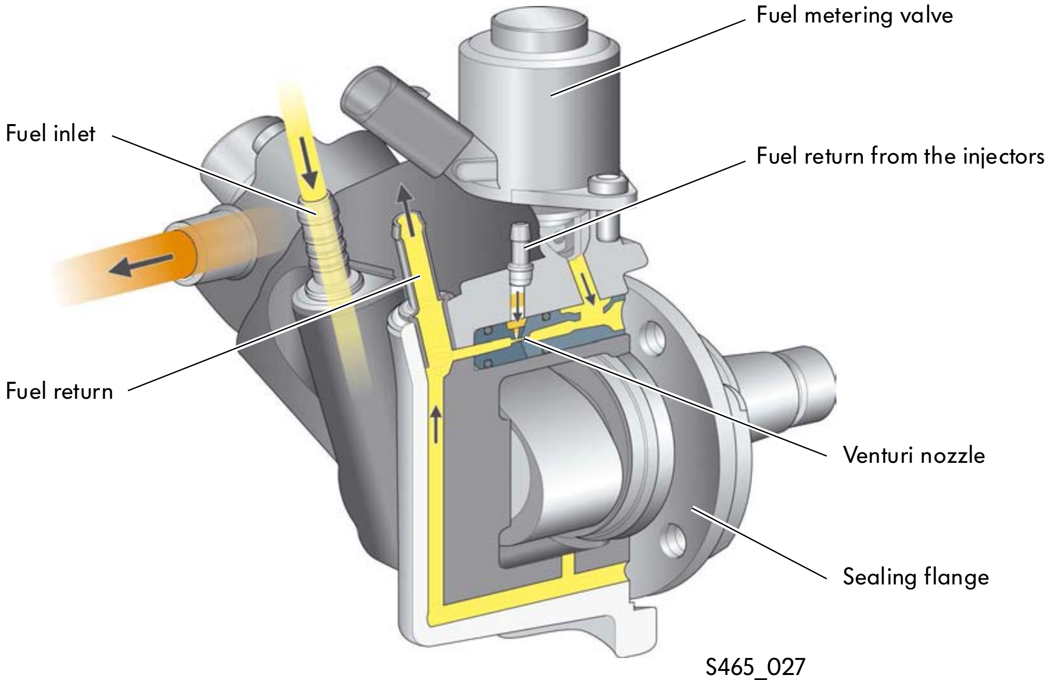
S465_073

Effects upon failure

The engine output is reduced. The engine management system operates in emergency running mode.

Venturi nozzle

The venturi nozzle generates negative pressure in the fuel return of the injectors. It has been integrated into the housing of the high-pressure pump.
The negative pressure in the injector fuel return aids fast opening and closing of the injectors during the injection process.



S465_027

How it works

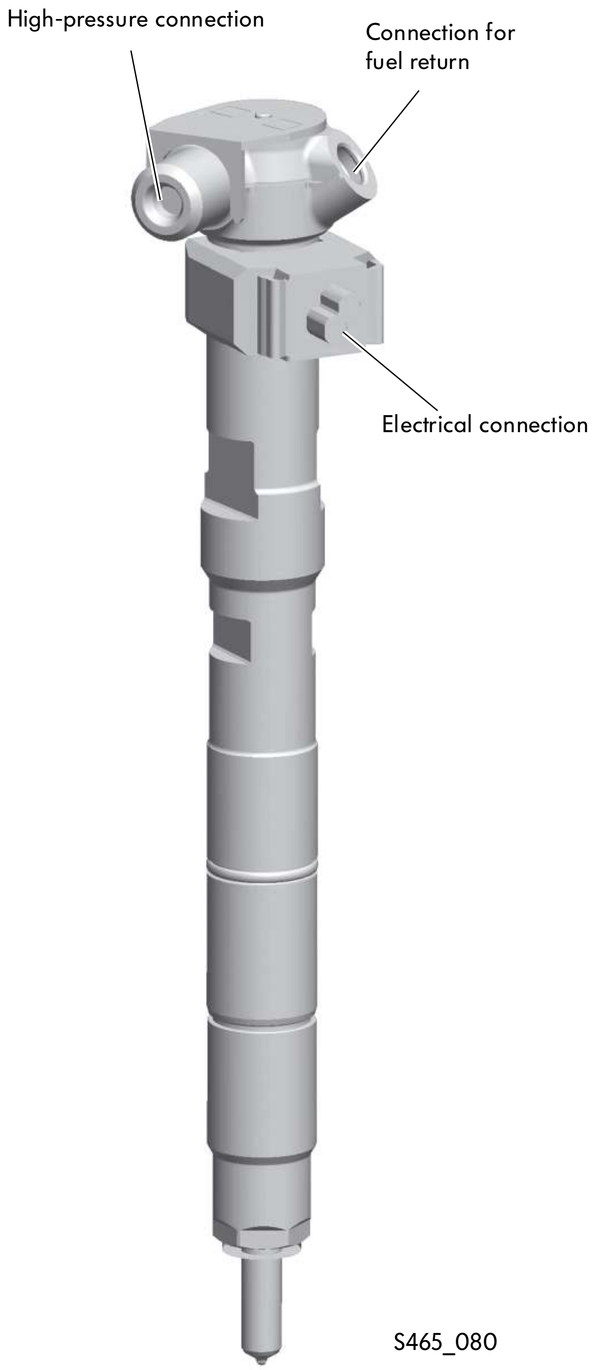
The fuel that is not required for injection is diverted by the fuel metering valve into the fuel return in the direction of the venturi nozzle.
The constricted cross-section of the funnel-shaped nozzle increases the flow rate of the fuel because the same quantity flows through everywhere.
The high flow rate at the narrowest point in the venturi nozzle creates a suction effect in the fuel return of the injectors.
This suction effect creates the negative pressure in the injector fuel return, which aids fast opening and closing of the injectors during the injection process.

If there are differences in the negative fuel pressure of the injectors, there may be a lack of power at high engine loads and faults could occur.

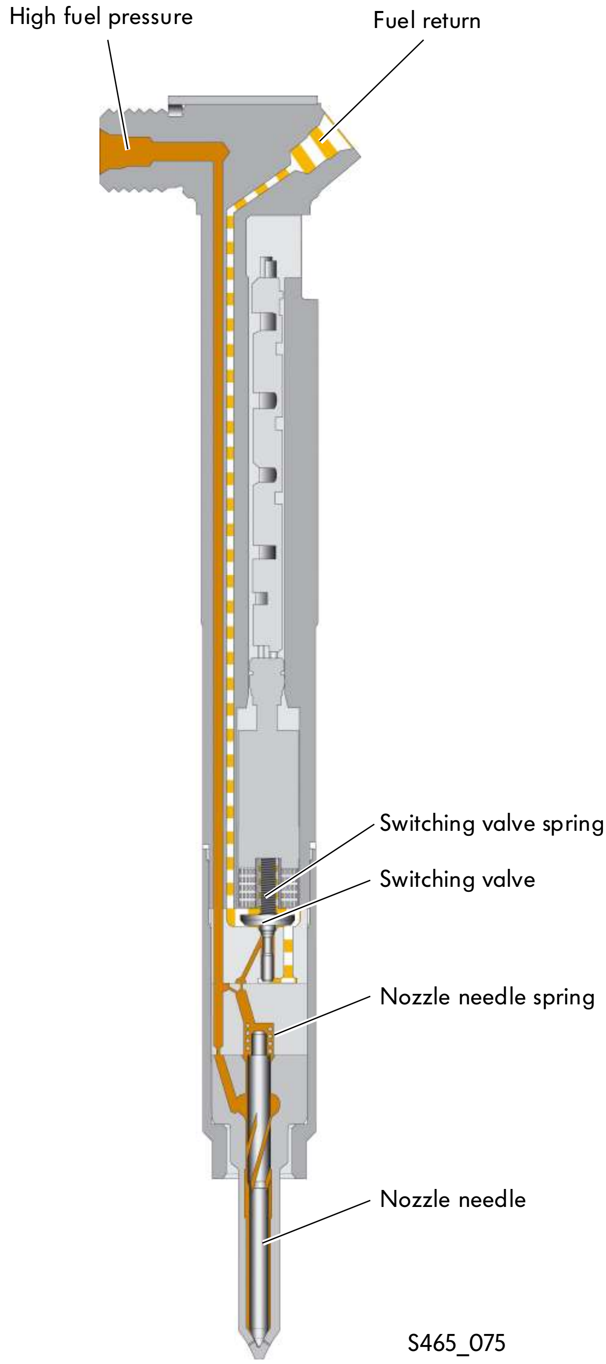
Injectors

The injectors are secured in the cylinder head with clamping pieces. They have the task of injecting the right quantity of fuel into the combustion chambers at the right time. They are actuated by the engine control unit.

Design



S465_080



S465_075

Injection process

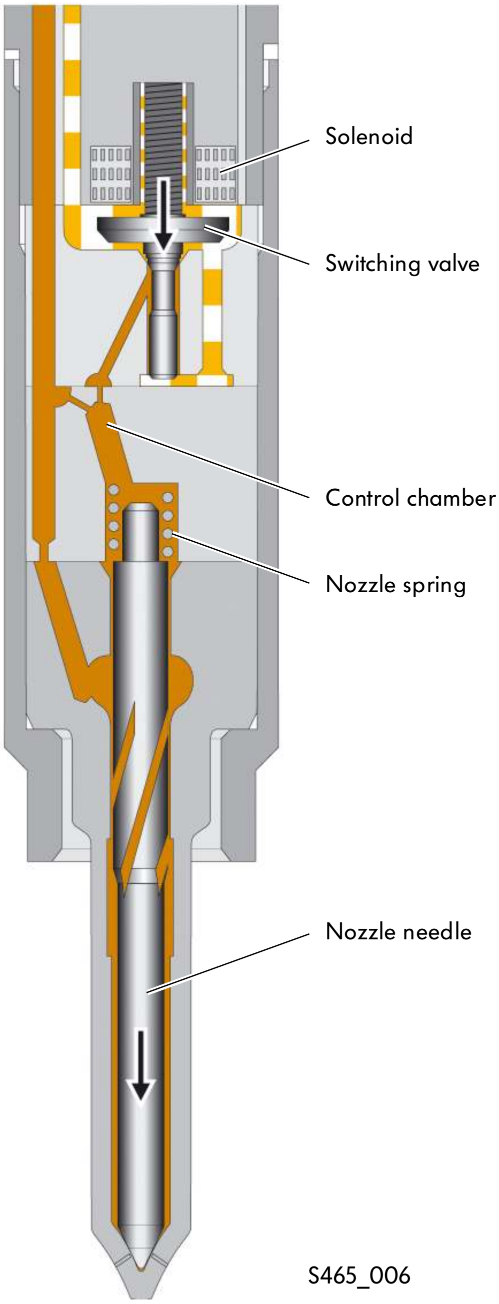
Injector in resting position

The injector is closed in its resting position.

The solenoid valve is not actuated.

The switching valve closes the path from the control chamber to the fuel return. High fuel pressure is present in the control chamber and at the nozzle needle.

The pressure conditions at the nozzle needle and in the control chamber are balanced. The nozzle needle is pushed into its seat by the force of the nozzle spring.



S465_006

Start of injection

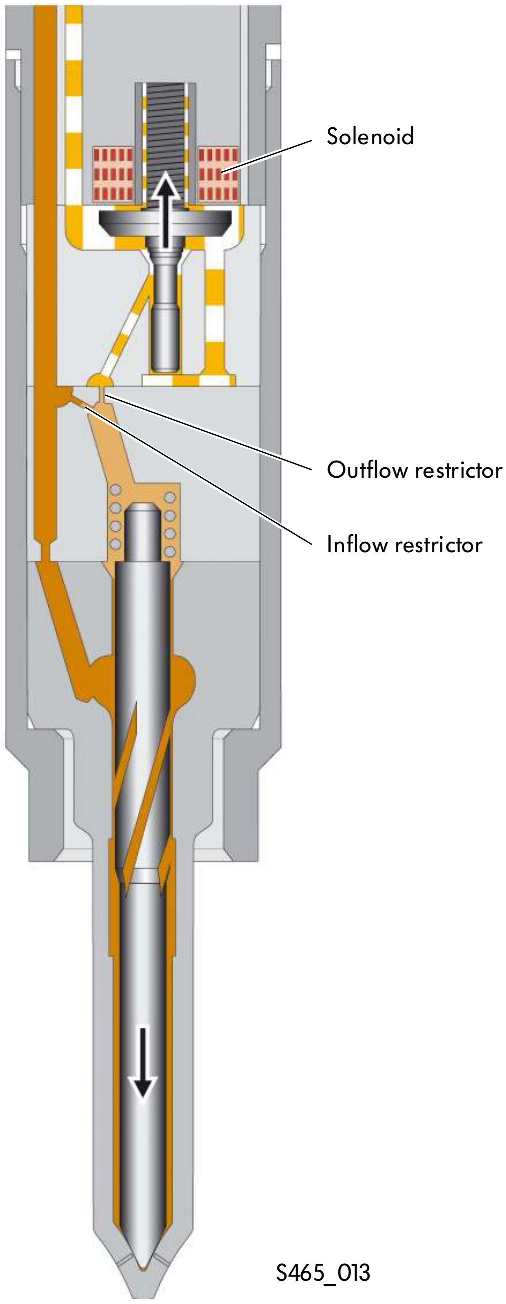
Phase 1

The start of injection is initiated by the engine control unit. It does so by actuating the solenoid valve.

A magnetic field is formed in the solenoid, which lifts the switching valve out of its seat.

The opening movement of the switching valve is supported by the negative pressure in the fuel return.

This opens the path from the control chamber to the fuel return. The fuel in the control chamber flows into the fuel return via the outflow restrictor. This reduces the fuel pressure in the control chamber that pushes the nozzle needle into its seat. The inflow restrictor to the control chamber is smaller than the outflow restrictor to prevent a quick pressure equilibrium.



S465_013

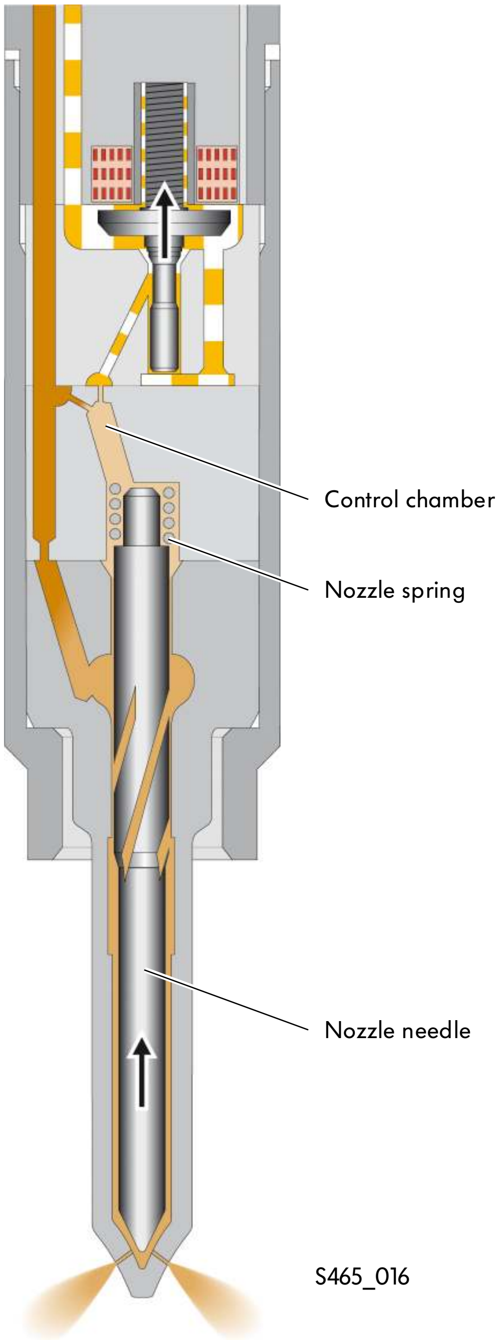
Start of injection

Phase 2

As soon as the fuel pressure at the nozzle needle exceeds the pressure in the control chamber and the force of the nozzle spring, the nozzle needle is lifted out of its seat and injection begins.

The negative pressure in the fuel return supports the drop in fuel pressure in the control chamber and thus increases the opening speed of the injector.

The opening travel of the nozzle needle is limited by the stop in the control chamber.



S465_016

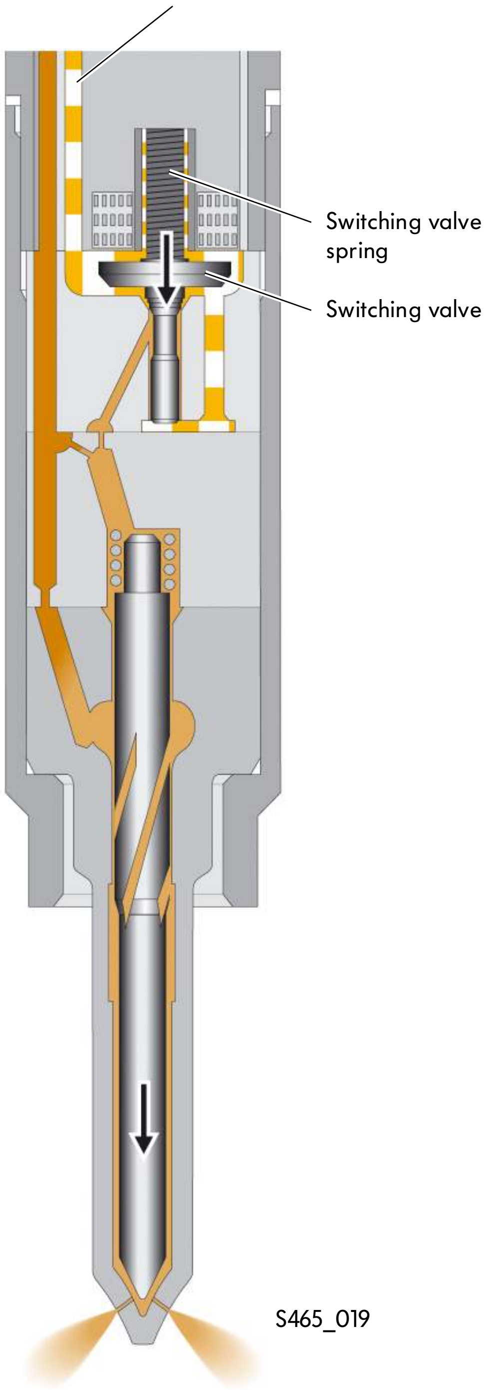
End of injection

Phase 1

The end of injection is initiated by the engine control unit. It does this by ending the actuation of the solenoid valve.

The switching valve is pushed into its seat by the force of the switching valve spring and thus closes the path from the control chamber to the fuel return.

The closing speed is increased by the negative pressure in the fuel return.



S465_019

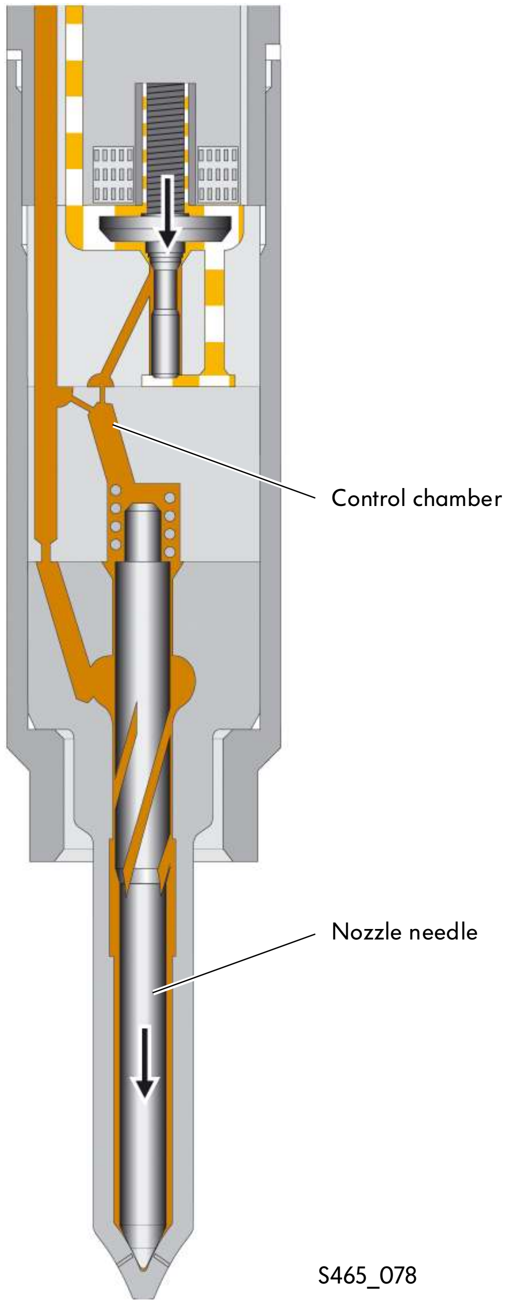
End of injection

Phase 2

In the control chamber, the fuel pressure rises again until it is as high as the pressure at the nozzle needle.

The force of the nozzle spring ends the equilibrium of forces above and below the nozzle needle and pushes the nozzle needle into its seat.

The injection process is completed and the injector is in its resting position again.



S465_078

The injection quantity is determined by the solenoid valve actuation duration and the rail pressure. The negative pressure in the fuel return allows fast movements of the solenoid valve. This allows several injections to be made per working cycle and the injection quantities to be adjusted precisely.

Correction value for the injection valves

There is a data carrier on the top of the injectors. In addition to manufacturer-specific details, the VW part number and a 20-digit correction value are stamped onto this data carrier.

The correction value compensates injection performance differences between the injectors that result from manufacturing tolerances.

The correction value is determined on a test rig during injector production. It indicates deviations from the specifications and thus describes the injection performance of the respective injector.

S465_098

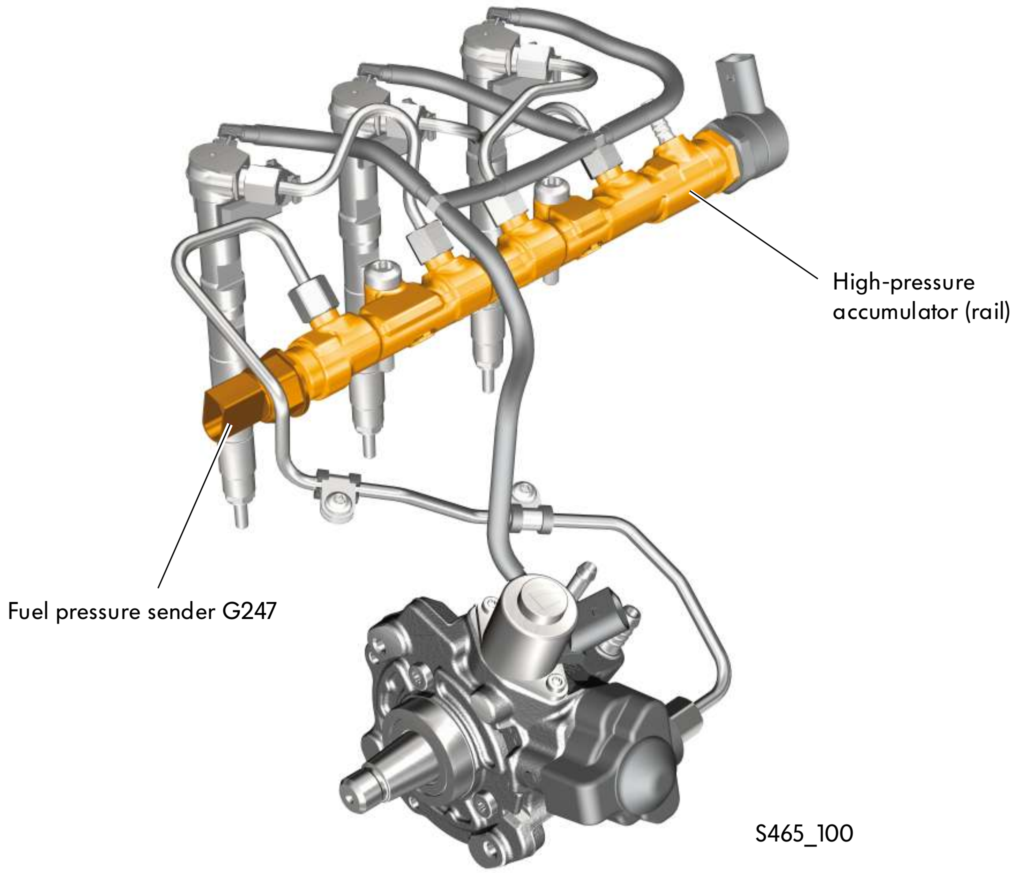
The engine control unit can use the correction value to control and correct the actuation of single injectors across the whole mapped range. This allows precise control of the injection quantities, which contributes to the reduction of fuel consumption and exhaust gas emissions as well as to quiet engine running.

S465_101

When injectors are replaced, the correction value must be entered in the guided fault finding system under the "Read/adapt injector correction values" menu option.

High-pressure accumulator (rail)

The rail is a high-pressure accumulator for the fuel that is delivered by the high-pressure pump.
It supplies the injectors with the quantity of fuel required for injection.



S465_100

Fuel pressure sender G247

The fuel pressure sender measures the current fuel pressure in the high-pressure accumulator (rail). Evaluation electronics in the fuel pressure sender convert the hydraulic pressure into a voltage signal that is evaluated by the engine control unit.

Signal use

The signal from the fuel pressure sender is used by the engine control unit to calculate the actuation duration of the injectors and the high-pressure regulation by the fuel metering valve.

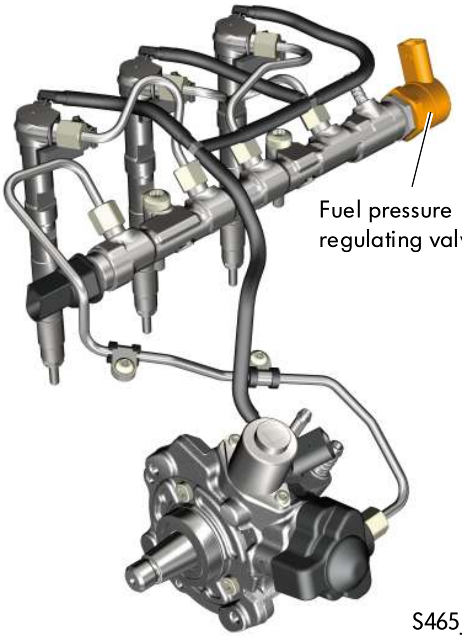
Effects of signal failure

The engine will not run if the fuel pressure sender fails.

Fuel pressure regulating valve N276

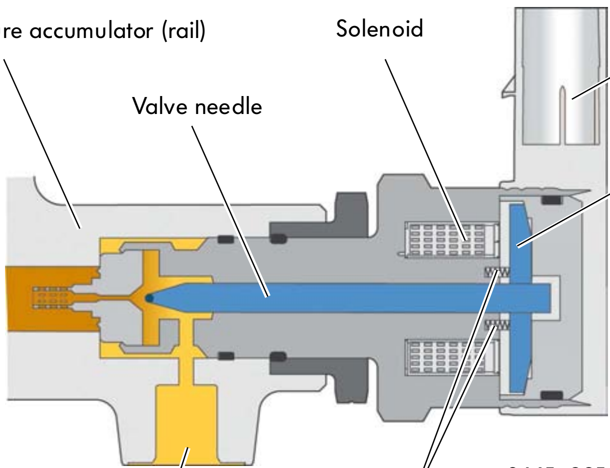
The fuel pressure regulating valve is located on the high-pressure accumulator (rail).

The engine control unit actuates the regulating valve with a pulse-width modulated signal and thus sets the fuel pressure in the high-pressure area.



S465_094

Design



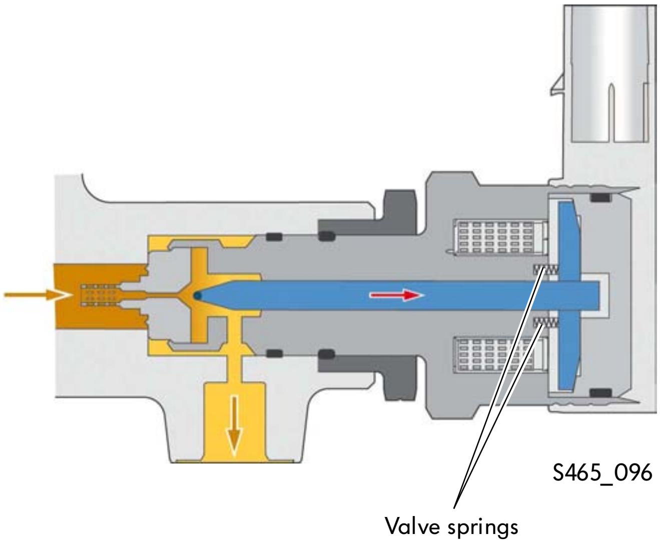
S465_095

How it works

Regulating valve in resting position (engine "off")

If the regulating valve is not actuated, the pressure regulating valve is opened by the valve springs.
The high-pressure area is connected to the fuel return.

This ensures a volume balance between the high-pressure and low-pressure fuel areas. Vapour bubbles, which can form in the high-pressure accumulator (rail) during the cooling process after the engine is switched off, are avoided and the starting behaviour of the engine is thus improved.

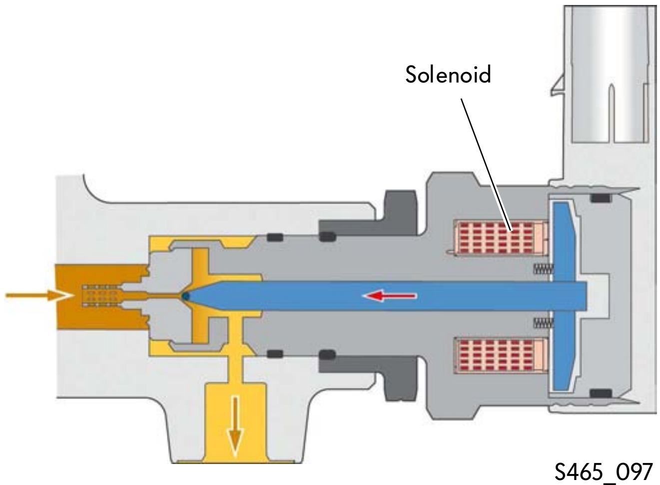


S465_096

Regulating valve actuated (engine "on")

To set the operating pressure of 230 to 1,800 bar in the high-pressure accumulator, the regulating valve is actuated by the engine control unit. This leads to a magnetic field in the solenoid. The valve armature is attracted and presses the valve needle into its seat. The fuel pressure in the high-pressure accumulator is therefore opposed by a magnetic force.

When the engine has reached operating temperature, the high fuel pressure is regulated exclusively by the fuel metering valve. The fuel pressure regulating valve is fully closed.



S465_097

Effects upon failure

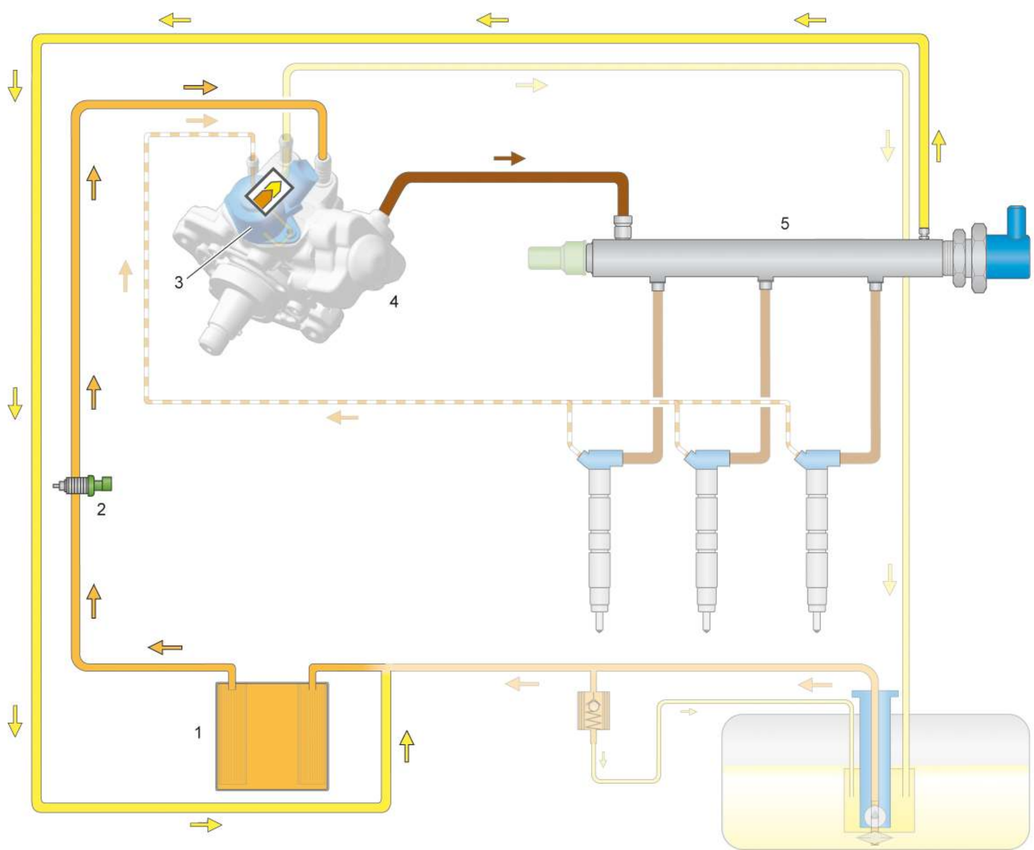
The engine will not run if the fuel pressure regulating valve fails because it is not possible to build up sufficient fuel pressure for fuel injection.

Pre-heating the fuel filter

When the fuel temperature is cold, warmed fuel from the high-pressure accumulator (rail) is directed into the supply line upstream of the fuel filter. This prevents the fuel filter becoming clogged with crystallised paraffin.

To allow the fuel to be warmed quickly when the engine is cold, the fuel metering valve N290 is regulated to supply more fuel than is required for injection to the pressure chamber of the high-pressure pump. The fuel warmed during pressurisation is sent from the high-pressure accumulator (rail) via the fuel pressure regulating valve N276 into the fuel filter return line.

As soon as the fuel reaches a certain temperature, the fuel pressure regulating valve remains fully closed. The high fuel pressure is then regulated exclusively by the fuel metering valve N290.



S465_099

Legend

1 - Fuel filter
2 - Fuel temperature sender G81
3 - Fuel metering valve N290
4 - High-pressure pump
5 - High-pressure accumulator (rail)
6 - Fuel pressure regulating valve N276

Engine Management

System overview

Sensors

Engine speed sender G28

Hall sender G40

Accelerator position sender G79
Accelerator position sender 2 G185

Air mass meter G70

Coolant temperature sender G62

Radiator outlet coolant temperature sender G83

Charge pressure sender G31
Intake air temperature sender G42

Fuel temperature sender G81

Fuel pressure sender G247

Knock sensor 1 G61

Exhaust gas recirculation potentiometer G212

Lambda probe G39

Exhaust gas pressure sensor 1 G450

Exhaust gas temperature sender 1 G235

Exhaust gas temperature sender 3 G495

Exhaust gas temperature sender 4 G648

Brake light switch F

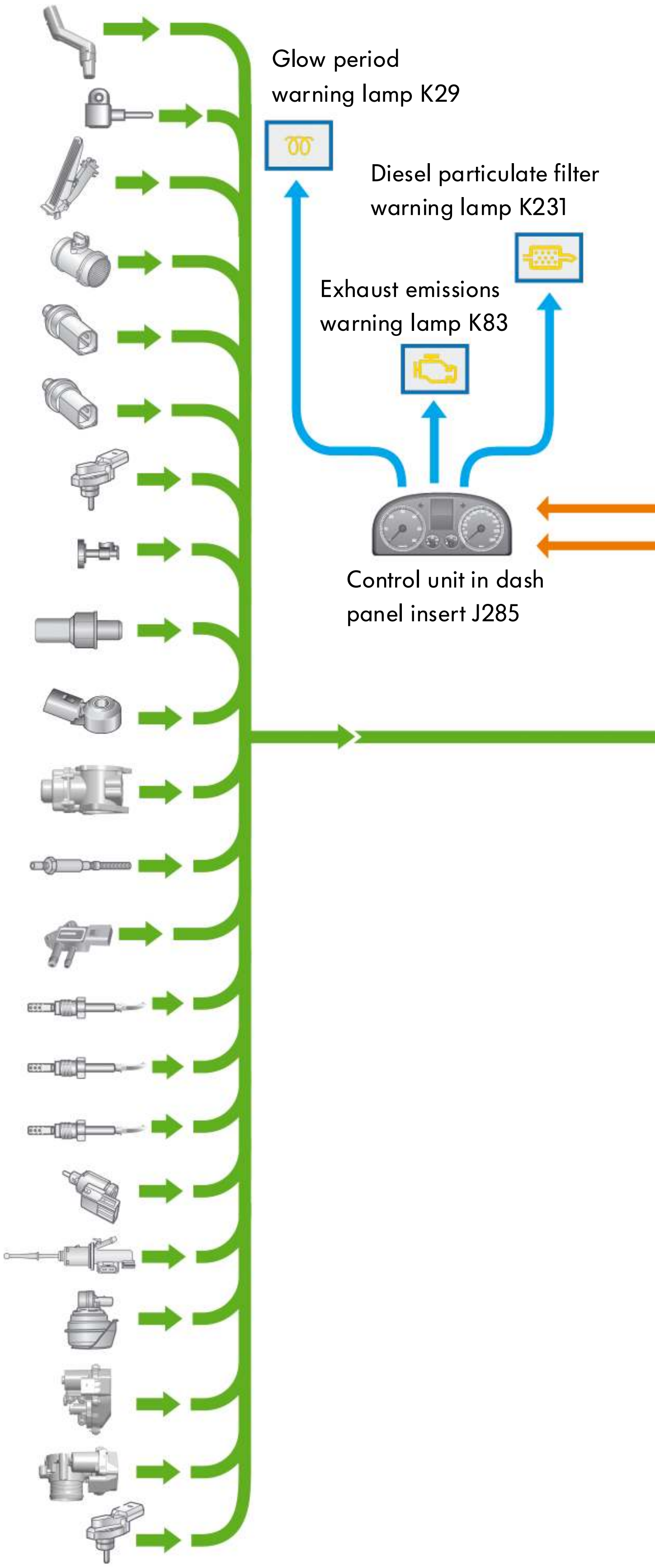
Clutch position sender G476

Position sender for charge pressure positioner G581

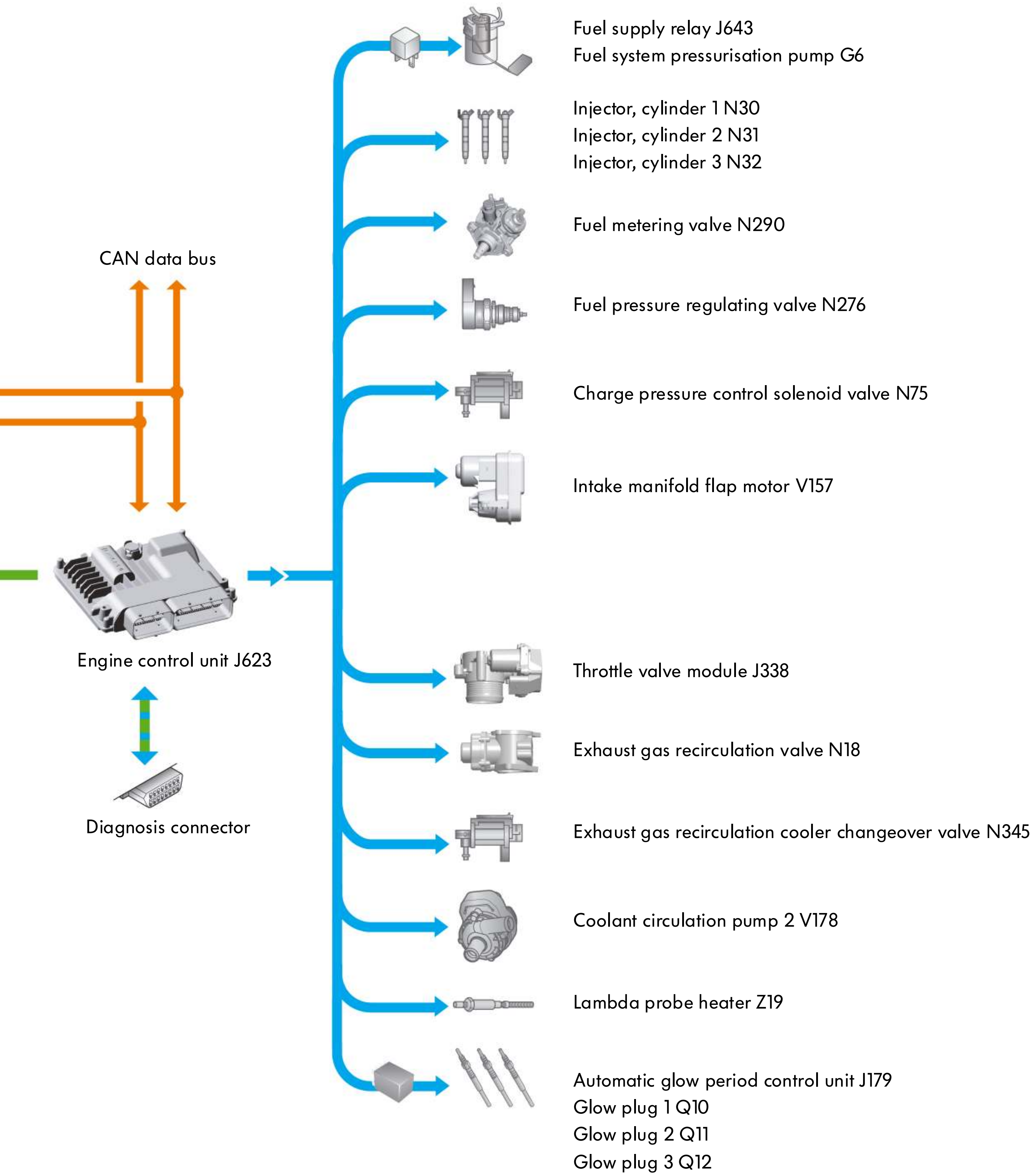
Intake manifold flap potentiometer G336

Throttle valve potentiometer G69

Oil level and oil temperature sender G266



Actuators



S465_076

Engine control unit

The engine management system for the 1.2l TDI engine with common rail injection system is named:

Delphi DCM 3.7

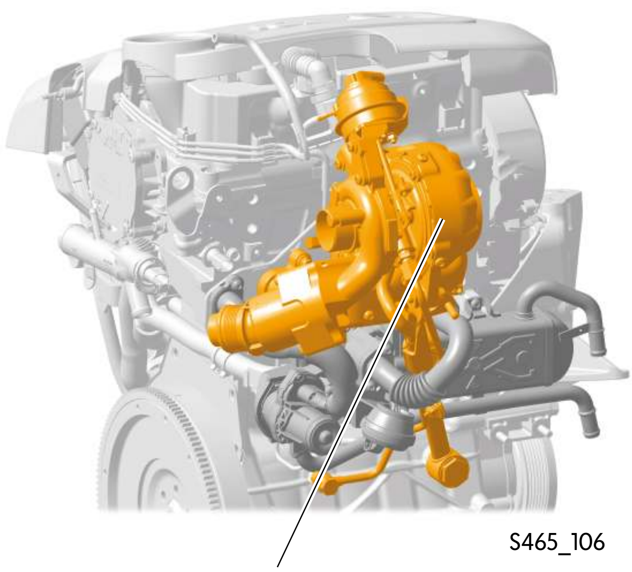
Delphi	=	manufacturer of engine management system
DCM	=	Diesel Control Module
3.7	=	development stage

S465_079

The engine management system checks all processes that are required for regulation of the injection system and control of the engine. In addition, the engine control unit communicates with control units for other vehicle systems via the CAN data bus to exchange information.

Turbocharger

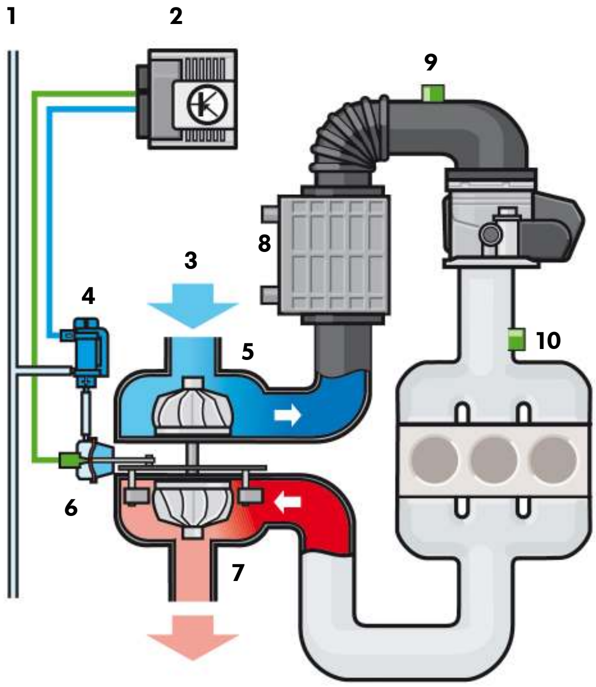
The charge pressure of the 1.2l TDI engine is generated by a turbocharger with adjustable guide vanes. The flow of exhaust gas to the turbine wheel of the turbocharger can be varied with the adjustable guide vanes. The advantage of this is that optimum charge pressure and therefore good combustion can be achieved throughout the entire engine speed range.



S465_106

The design and function of the turbocharger are explained in self-study programme no. 190 “Adjustable Turbocharger”.

Charge pressure regulation



S465_077

Legend

1 - Vacuum system
2 - Engine control unit J623
3 - Intake air
4 - Charge pressure control solenoid valve N75
5 - Turbocharger compressor
6 - Vacuum unit with position sender for charge pressure positioner G581
7 - Exhaust turbine with guide vane adjustment
8 - Charge air cooler
9 - Intake air temperature sender G42
10 - Charge pressure sender G31

The charge pressure regulation controls the quantity of air that is compressed by the turbocharger.

The turbocharger increases the pressure in the intake system of the engine so that a greater quantity of air enters the cylinder on the intake stroke. This provides more oxygen for combustion of a correspondingly larger quantity of fuel. The result is increased output with the same displacement and the same engine speed.

An increase in output is also obtained by using a charge air cooler. The combustion air drawn in through the air filter is heated greatly on the way to the engine, particularly in the turbocharger. The quantity of air and thus the quantity of oxygen available for combustion are reduced. The air is cooled again in the charge air cooler and the air density is thus further increased.

You will find further information on charge pressure regulation in self-study programme no. 403 “The 2.0l TDI Engine with Common Rail Injection System”.

Throttle valve module J338

The throttle valve module is mounted on the engine intake manifold.

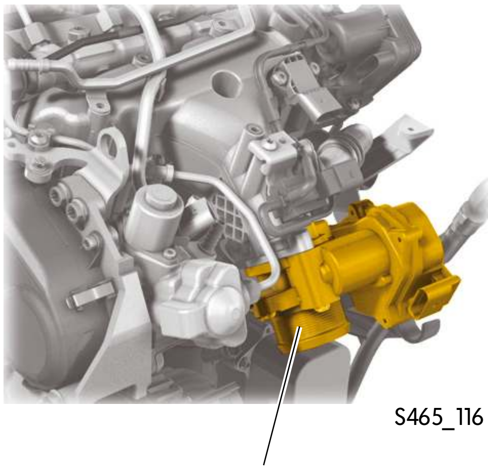
There is an electric motor in the throttle valve module that operates the throttle valve via gears. Adjustment of the throttle valve is infinite and can therefore be adapted to the relevant engine load and speed.

The throttle valve module has the following tasks:

In certain operating situations, the throttle valve creates a difference between the intake manifold pressure and the exhaust gas pressure. Effective exhaust gas recirculation is achieved due to the pressure difference.

The throttle valve is used to regulate the intake air quantity when the diesel particulate filter is in regeneration mode.

The valve is closed when the engine is switched off. Less air is therefore drawn in and compressed, as a result of which the engine stops smoothly.



S465_116

Throttle valve module J338 with throttle valve potentiometer G69

Effect upon failure

In the event of failure, correct regulation of the rate of exhaust gas recirculation is impossible. There is no active regeneration of the diesel particulate filter.

You will find more detailed information on the throttle valve module in self-study programme no. 368 “The 2.0l 125kW TDI engine with 4-valve technology”.

Throttle valve potentiometer G69

The throttle valve potentiometer has been integrated into the throttle valve drive. The sensor element detects the current position of the throttle valve.

Signal use

The engine control unit uses the signal to recognise the current position of the throttle valve. This information is required for regulation of the exhaust gas recirculation and regeneration of the particulate filter.

Effects upon failure

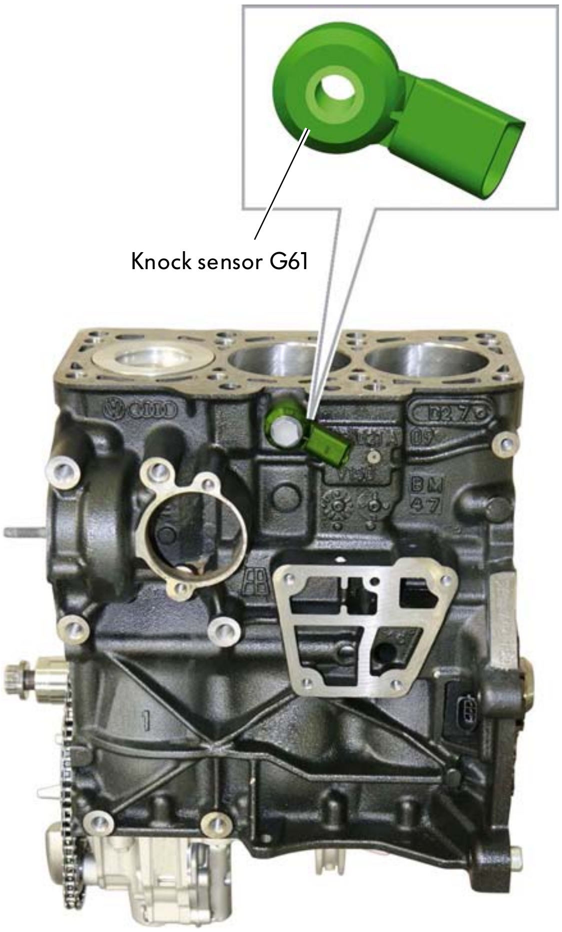
In the event of failure, exhaust gas recirculation is switched off and there is no active regeneration of the diesel particulate filter.

Sensors

Knock sensor G61

The knock sensor is a sensor that picks up the vibrations of the engine and sends them to the engine control unit in the form of a signal. In the diesel engine, the knock sensor recognises the combustion process at the respective cylinder allowing the engine control unit to then adjust the actuation of the corresponding injector.

The knock sensor is located in the cylinder block next to cylinder 2. The position has been selected so that the best possible signal can be received from all cylinders.



S465_089

Signal use

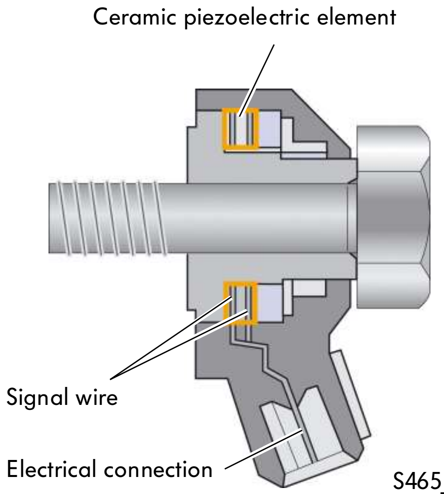
The engine control unit uses the knock sensor signal to monitor the combustion process and thus the actual start of injection in the respective cylinder. The engine control unit can therefore constantly adjust the actuation of the injector. As a result, any change in the performance of the injectors, which may occur over a long period of operation, can be compensated. The signal from the knock sensor allows precise metering of even the smallest injection quantities. As a result, fuel consumption and exhaust gas emissions are reduced.

Please observe the information on fitting the knock sensor to the cylinder block in the workshop manual. Using an incorrect torque can lead to damage or a distorted signal.

Engine Management

Design of knock sensor

The design of the knock sensor for the diesel engine corresponds with one for petrol engines.
The structure-borne sound vibrations and the structure-borne sound of the engine are transmitted to the ceramic piezoelectric element in the sensor.
These vibrations generate a voltage in the ceramic piezoelectric element that is sent to the engine control unit in the form of a signal.

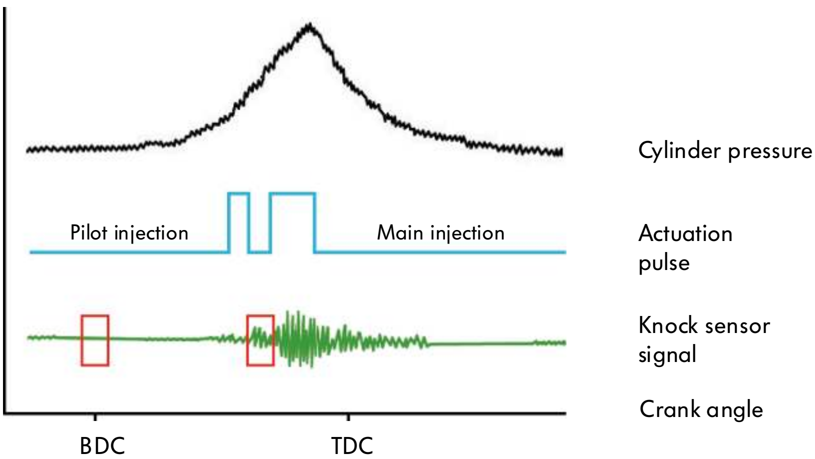


S465_115

Injection recognition function

In order to distinguish the structure-borne sound vibrations of the combustion process from the structure-borne sound vibrations of the background noise in the crankshaft drive, the noises are detected by the engine control unit in two time windows. Both measuring results are then correlated and compared.
In the first time window, the time of measurement is set so that no combustion can occur – for example, at bottom dead centre of the crankshaft.
The intensity of combustion after a pilot injection is determined in the second time window. The time of the measurement is selected so that only the combustion noises caused by the pilot injection are detected. The second time window is therefore immediately before the main injection.

Injection process with a pilot injection



S465_103

Function of injection adjustment

A specification for the minimum actuation time of the solenoid valve for injection is stored in the engine control unit. This actuation pulse must at least be present to allow injection.

If the actuation pulse is too low, there is no injection since the actuation time is too short for the solenoid valve to lift the nozzle needle inside the injector.

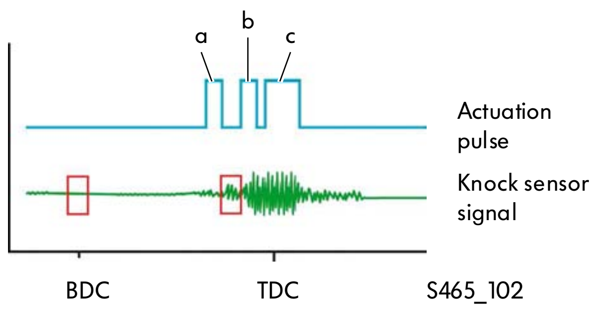
If the actuation pulse is too large, too much fuel is injected since the nozzle needle in the injector stays open longer than is specified.

When the injection is adjusted, the deviation from the minimum actuation time for an injection is calculated using the stored specification. If the minimum actuation time deviates from the specification, the engine control unit corrects the actuation time of the solenoid valve.

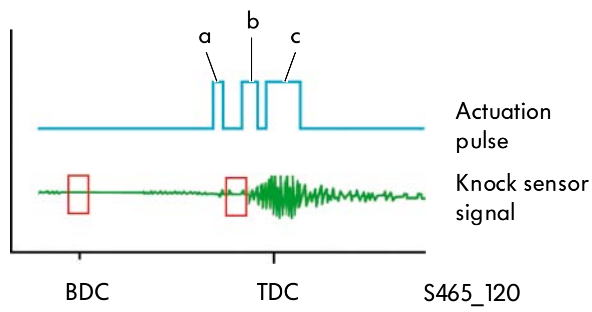
Learning process

To find out the minimum actuation pulse for an injector, the engine control unit actuates the solenoid valve for a set time. Then, depending on the combustion noise, the actuation time of the solenoid valve is shortened or lengthened until there is no longer a pilot injection. This actuation value is stored as a correction value in the engine control unit.

Long actuation pulse for pilot injection



Short actuation pulse for pilot injection



a) Pilot injection for injection adjustment learning function
b) Pilot injection for noise reduction
c) Main injection

To reduce the combustion noises during the learning process for injection adjustment, there is another pilot injection immediately before the main injection.

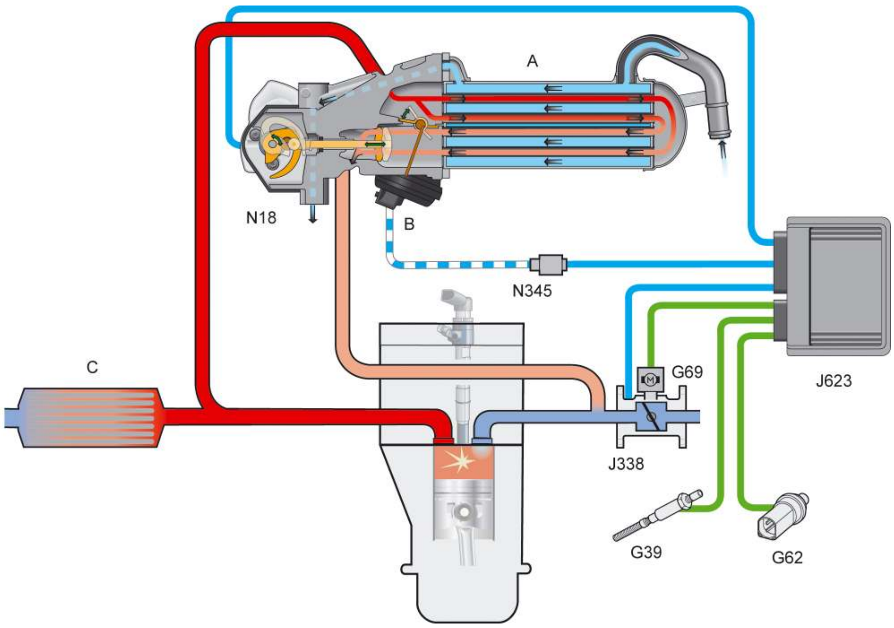
The minimum actuation time is calculated separately for each cylinder when the engine has reached operating temperature and in certain operating conditions.

Effects of signal failure

A fault is recorded in the engine control unit when the knock sensor signal fails. The injectors are actuated with the actuation pulse values stored in the engine control unit.

Exhaust gas recirculation system

Exhaust gas recirculation is a system for reducing nitrogen oxide emissions. Thanks to exhaust gas recirculation, part of the exhaust gases are returned to the combustion process. The reduction in the oxygen concentration of the fuel/air mixture, which results from this process, causes slower combustion. This lowers the combustion peak temperature and reduces the nitrogen oxide emissions.



S465_105

Legend

G39 Lambda probe
G62 Coolant temperature sender
G69 Throttle valve potentiometer
J338 Throttle valve module
J623 Engine control unit

N18 Exhaust gas recirculation valve
N345 Exhaust gas recirculation cooler change-over valve
A Exhaust gas recirculation module
B Vacuum unit
C Catalytic converter

The exhaust gas recirculation quantity is controlled on the basis of a map in the engine control unit. The engine speed, injection quantity, intake air mass, the intake air temperature and the air pressure are taken into account.

A broadband lambda probe is located upstream of the particulate filter in the exhaust system. The lambda probe enables measurement of the oxygen content in the exhaust gas over a wide measuring range. The signal from the lambda probe is used as a correction value for regulating the exhaust gas recirculation quantity in the exhaust gas recirculation system.

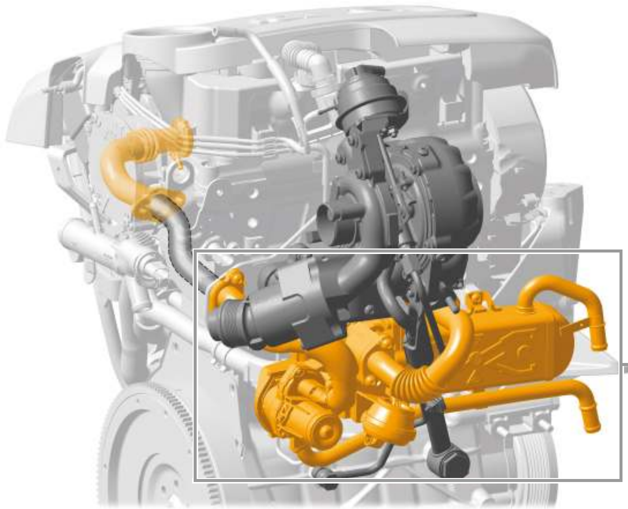
An exhaust gas recirculation cooler allows the combustion temperature to be lowered further by cooling the recirculated exhaust gases. It also enables a greater quantity of exhaust gases to be recirculated.

This effect is boosted further by the low-temperature exhaust gas recirculation system.

The low-temperature exhaust gas recirculation system is explained on page 13 of this book.

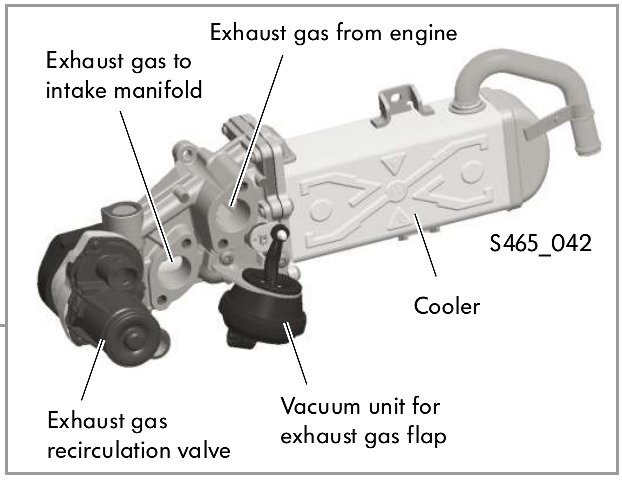
Exhaust gas recirculation module

On the 1.2l TDI engine, the exhaust gas recirculation valve and the exhaust gas cooler with exhaust gas flap have been combined in a single module. The advantages of the modular design are a compact space requirement and, at the same time, a shorter control path. The exhaust gas recirculation module is bolted to the exhaust side of the cylinder head and the exhaust manifold. The module is connected to the intake manifold directly through the cylinder head. This allows additional cooling of the recirculated exhaust gases.



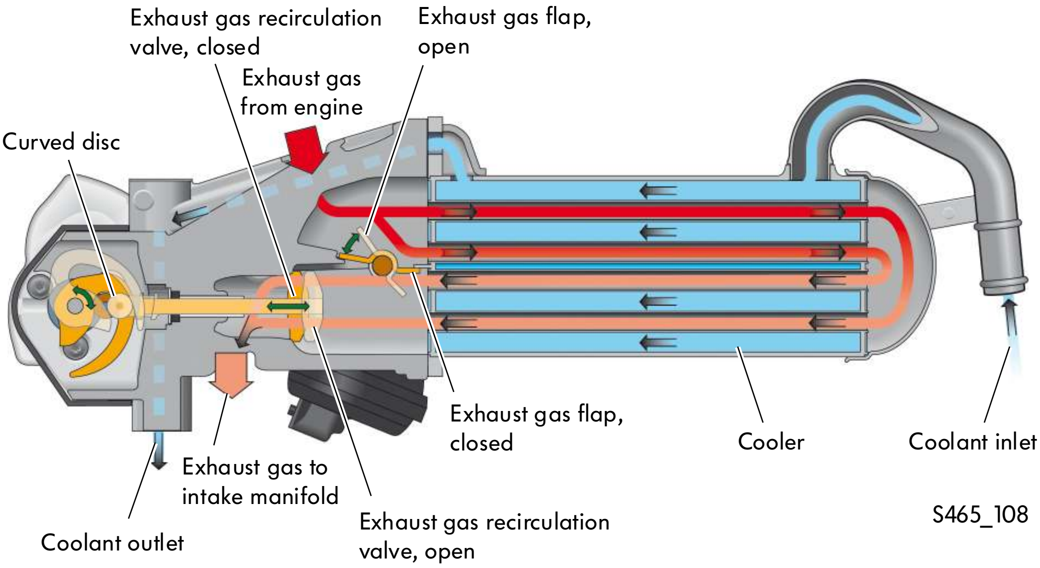
S465_005

Exhaust gas recirculation module



S465_042

Design

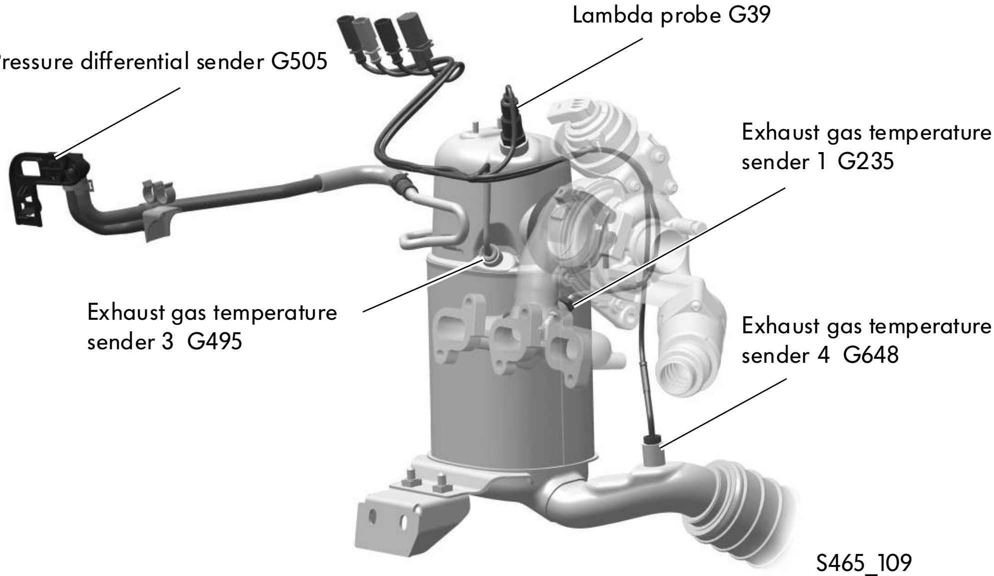


S465_108

You will find further information on how the exhaust gas recirculation system works in self-study programme no. 316 "The 2.0 ltr. TDI engine".

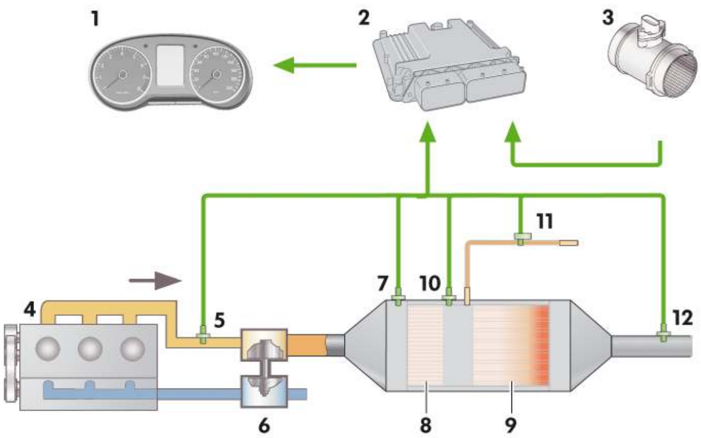
Diesel particulate filter system

In addition to measures inside the engine, the carbon particles formed during combustion are reduced by a diesel particulate filter.
The diesel particulate filter is located in one housing together with the oxidising catalytic converter. In the Polo, the housing has been positioned close to the engine so that the oxidising catalytic converter and diesel particulate filter reach operating temperature quickly.



S465_109

System overview



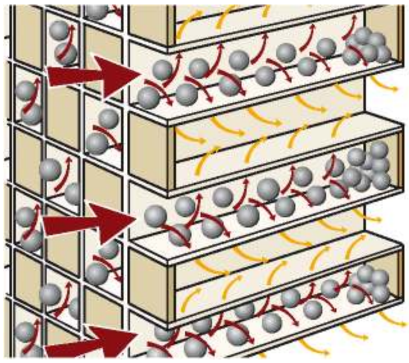
S465_110

Legend

1 - Control unit in dash panel insert J285
2 - Engine control unit J623
3 - Air mass meter G70
4 - Diesel engine
5 - Exhaust gas temperature sender 1 G235
6 - Turbocharger
7 - Lambda probe G39
8 - Oxidising catalytic converter
9 - Diesel particulate filter
10 - Exhaust gas temperature sender 3 G495
11 - Pressure differential sender G505
12 - Exhaust gas temperature sender 4 G648

Design

The diesel particulate filter consists of a honeycombed ceramic body, which is divided into numerous small channels. These channels are sealed at alternating ends and thus subdivided into inlet and outlet channels.



S465_112

Function

The exhaust gas, which contains carbon, flows through the porous filter walls of the intake channels. The carbon particles, unlike the gaseous components of the exhaust gas, are deposited on the filter walls of the intake channels.

Regeneration

To prevent the particulate filter from becoming blocked with carbon particles, thereby impeding its function, it must be regenerated on a regular basis.

During the regeneration process, the carbon particles that have collected in the particulate filter are burned.

Passive regeneration

During passive regeneration, the carbon particles are continuously combusted without engine management system intervention. This mainly occurs at high engine loads and exhaust gas temperatures of 350°C-500°C.

In this case, the carbon particles are converted into carbon dioxide via a reaction with nitrogen dioxide.

Active regeneration

In a large proportion of the operating range, the exhaust gas temperatures are too low for passive regeneration. Since no more carbon particles can be oxidised passively, active regeneration is initiated by the engine control system as soon as a certain carbon level is reached in the filter. Secondary injections are used to increase the exhaust gas temperature to approx. 550°C - 650°C and the carbon particles are burnt to form carbon dioxide.

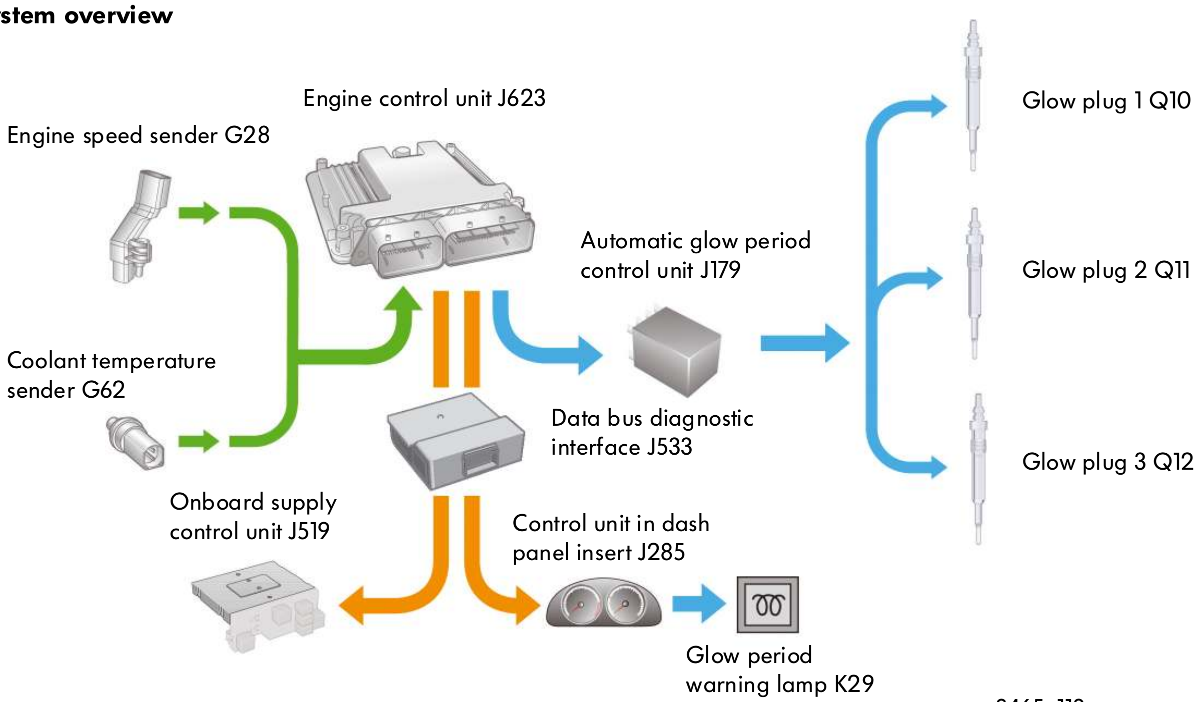
You will find detailed information on the diesel particulate filter system in self-study programme no. 336 “The catalytically coated diesel particulate filter” and no. 403 “The 2.0l TDI Engine with Common Rail Injection System”.

Glow plug system

A fast-start glow plug system allows the 1.2l TDI engine to be started without a long glow period in a way comparable with petrol engines.

The glow plugs reach up to 1,000°C within 2 seconds thanks to an extremely short heating time. Therefore a "petrol engine-like" immediate engine start is possible in almost all climatic conditions.

System overview



S465_113

Automatic glow period control unit J179

The automatic glow period control unit receives the information for the glow function from the engine control unit. The start and duration of the glow period, the activation frequency and the on-off ratio for the glow plugs are therefore determined by the engine control unit.

The automatic glow period control unit has the following functions:

1. Switching the glow plugs with a PWM signal (PWM = pulse-width modulated)
   - PWM low level = glow plug powered
   - PWM high level = glow plug not powered

2. Integrated overvoltage and overtemperature shut-off

3. Individual glow plug monitoring
   - Detection of overcurrent and short-circuit in the glow circuit
   - Glow electronics diagnosis
   - Detection of an open glow circuit in the event of glow plug failure

Glowing

The steel glow plugs are activated by the engine control unit via the automatic glow period control unit J179 with the aid of a pulse-width modulated signal (PWM signal). The voltage at the glow plugs is adjusted via the frequency of the PWM pulses. For rapid starting at outside temperatures below 18 °C, the maximum voltage of 11.5 V is applied for glowing. This high voltage guarantees that the glow plug is heated to over 1,000°C within a short time (max. 2 seconds). This reduces the engine glow period.

Post-start glowing

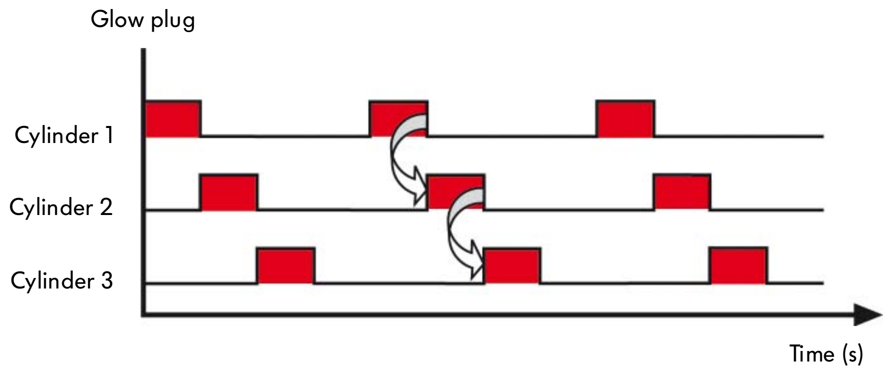
By continuously reducing the on-off ratio of the PWM signal, the voltage for post-start glowing is adjusted to the rated voltage of 4.4V depending on the operating point.

Post-start glowing is carried out for a maximum of 5 minutes after starting the engine up to a coolant temperature of 18°C.

Post-start glowing helps reduce hydrocarbon emissions and combustion noises during the engine warm-up phase.

Phase-shifted activation of the glow plugs

In order to relieve the burden on the onboard supply voltage during the glow phases, the glow plugs are activated phase-shifted. The falling signal edge always activates the next glow plug.



S465_119

Start/stop system

The 1.2l TDI engine fitted in the Polo Blue Motion comes with a start/stop system as standard.

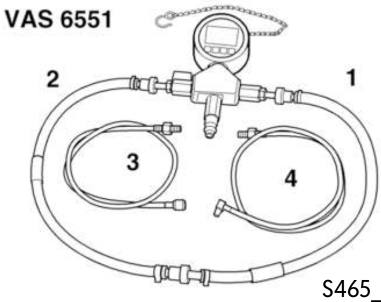
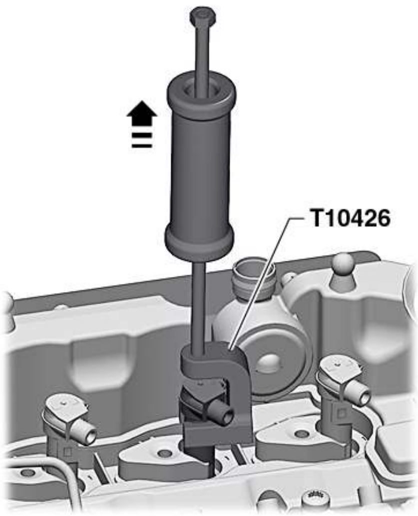
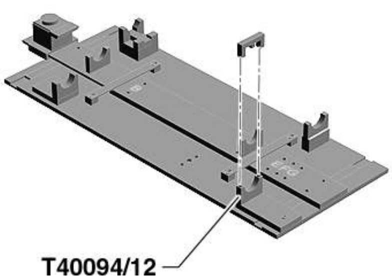
The start/stop system is used to reduce fuel consumption, exhaust gas emissions and noise. The engine is automatically switched off when the vehicle is stationary and is automatically restarted when the driver wants to pull away.

The start/stop function has been integrated into the engine control unit software. The system uses numerous signals from various sensors and vehicle systems to check the switch-on and -off conditions and operate the start/stop system.
In certain operating situations and how often the engine is switched off depends on a wide range of factors.
The basic requirement is that the comfort and safety of occupants must be maintained. If comfort and safety could be affected, the combustion engine will not be switched off even when the start/stop system is activated. If necessary, the engine will continue to operate the comfort- and safety-relevant components.

S465_118

You will find detailed information on the start/stop system in self-study programme no. 426 “Start/Stop System 2009”.

Special tools and workshop equipment

Description	Tool/workshop equipment	Application
Pressure tester VAS 6551 with adapter hoses VAS 6551/1, VAS 6551/2, VAS 6551/3, VAS 6551/4,	 S465_117	For testing the low-pressure fuel system and the fuel pump
Puller T 10426	 S465_090	For removing injectors
Adapter for camshaft fitting tool T 40094/12	 S465_091	For fitting the camshafts

Test Yourself

Which answer is correct?

One or several of the given answers may be correct.

1. Which statement about the fuel system pressurisation pump for the 1.2l TDI CR engine is correct?

☐ a) The fuel pump delivers the fuel from the fuel tank to the high-pressure pump at a pressure of approx. 1 bar.

☐ b) The fuel pump generates a pressure of approx. 6 bar in the fuel system supply line.

☐ c) The fuel pump is used exclusively to drive the suction jet pump in the fuel tank.

2. What is the purpose of the negative pressure in the fuel return of the injectors for the 1.2l TDI CR engine?

☐ a) The negative pressure actuates the switching valves in the injectors.

☐ b) The negative pressure allows fast opening and closing of the injectors.

☐ c) The negative pressure regulates the high fuel pressure in the fuel system.

3. How is the high fuel pressure regulated on the 1.2l TDI CR engine when the engine has reached operating temperature?

☐ a) The high fuel pressure is regulated exclusively by the fuel metering valve. The fuel pressure regulating valve is fully closed.

☐ b) The high fuel pressure is regulated exclusively by the fuel pressure regulating valve. The fuel metering valve is fully closed.

☐ c) The high fuel pressure is regulated by actuation of both the fuel metering valve and the fuel pressure regulating valve.

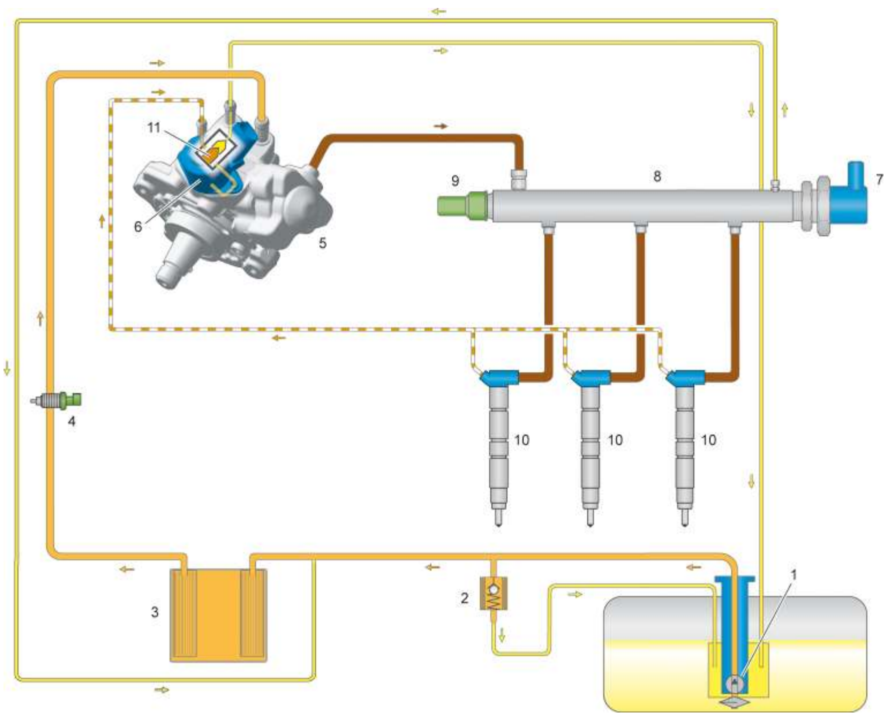
4. What is the purpose of the knock sensor on the 1.2l TDI CR engine?

☐ a) The knock sensor is used to adjust the combustibility of the fuel for the start of injection.

☐ b) The signal from the knock sensor is used by the engine control unit to recognise the actual start of injection at the respective injector.

☐ c) The signal from the knock sensor is used by the engine control unit to recognise knocking combustion and sets the start of injection to late.

5. **Please fill in the missing terms:**



S465_047

1 - ....

2 - ....

3 - Fuel filter

4 - ....

5 - ....

6 - ....

7 - ....

8 - High-pressure accumulator (rail)

9 - ....

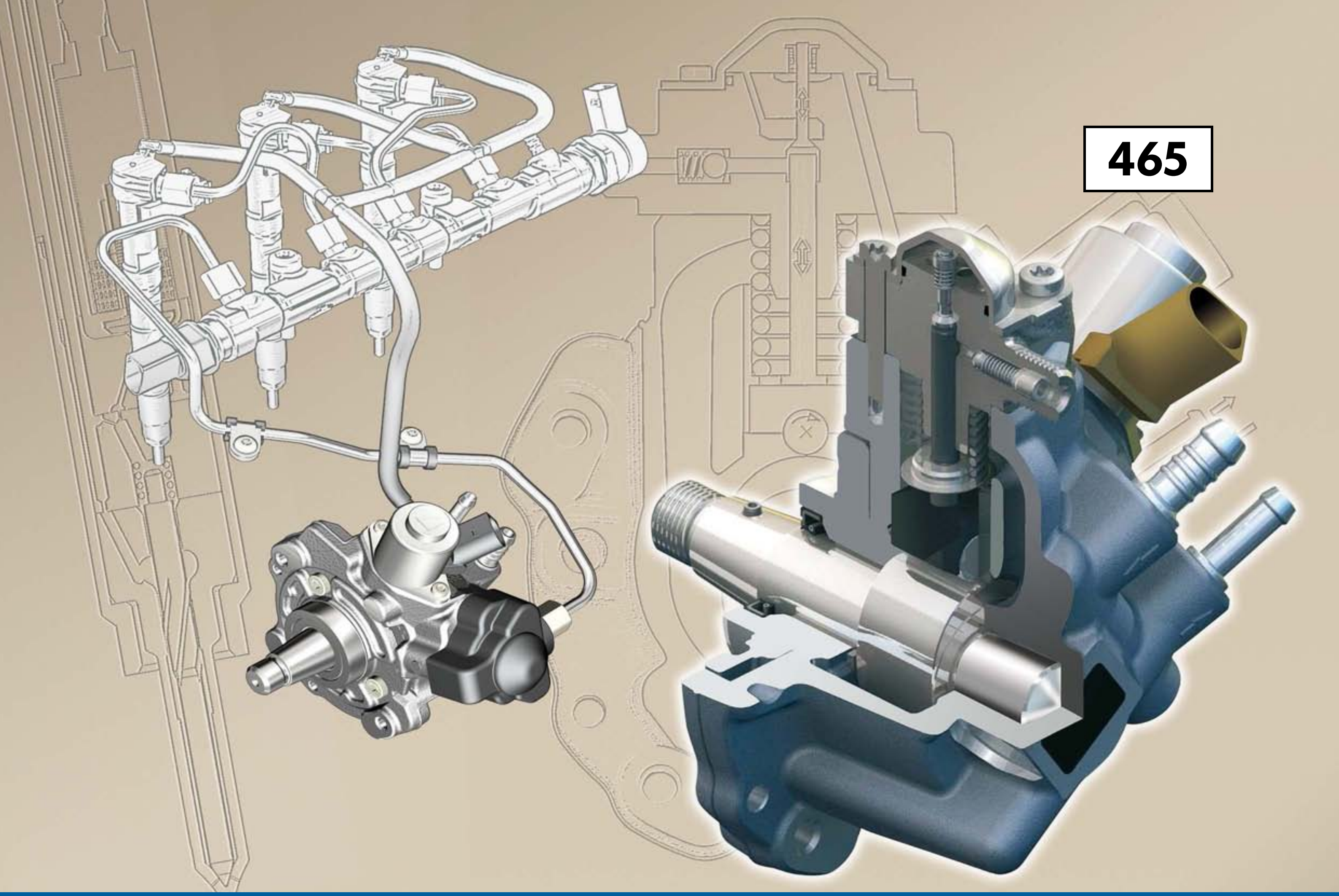
10 - ....

11 - ....

Answers:

1. b; 2. b; 3. a; 4. b;

5. 1 - Fuel system pressurisation pump G6
2 - Pressure regulator for fuel supply line
4 - Fuel temperature sender G81
5 - High-pressure pump
6 - Fuel metering valve N290
7 - Fuel pressure regulating valve N276
9 - Fuel pressure sender G247
10 - Injectors N30, N31, N32
11 - Venturi nozzle



000.2812.31.20 Technical status 07.2010

Volkswagen AG
After Sales Qualifizierung
Service Training VSQ-1
Brieffach 1995
D-38436 Wolfsburg