227

Service.

3,3 l V8 TDI Common Rail Injection System

Construction Features and Functions

Self-Study Programme 227

For internal use only

With its TDI engines, Audi AG has been a leader in diesel development since 1989. Its latest technological innovation, the unique V8 TDI bears testimony to this fact.

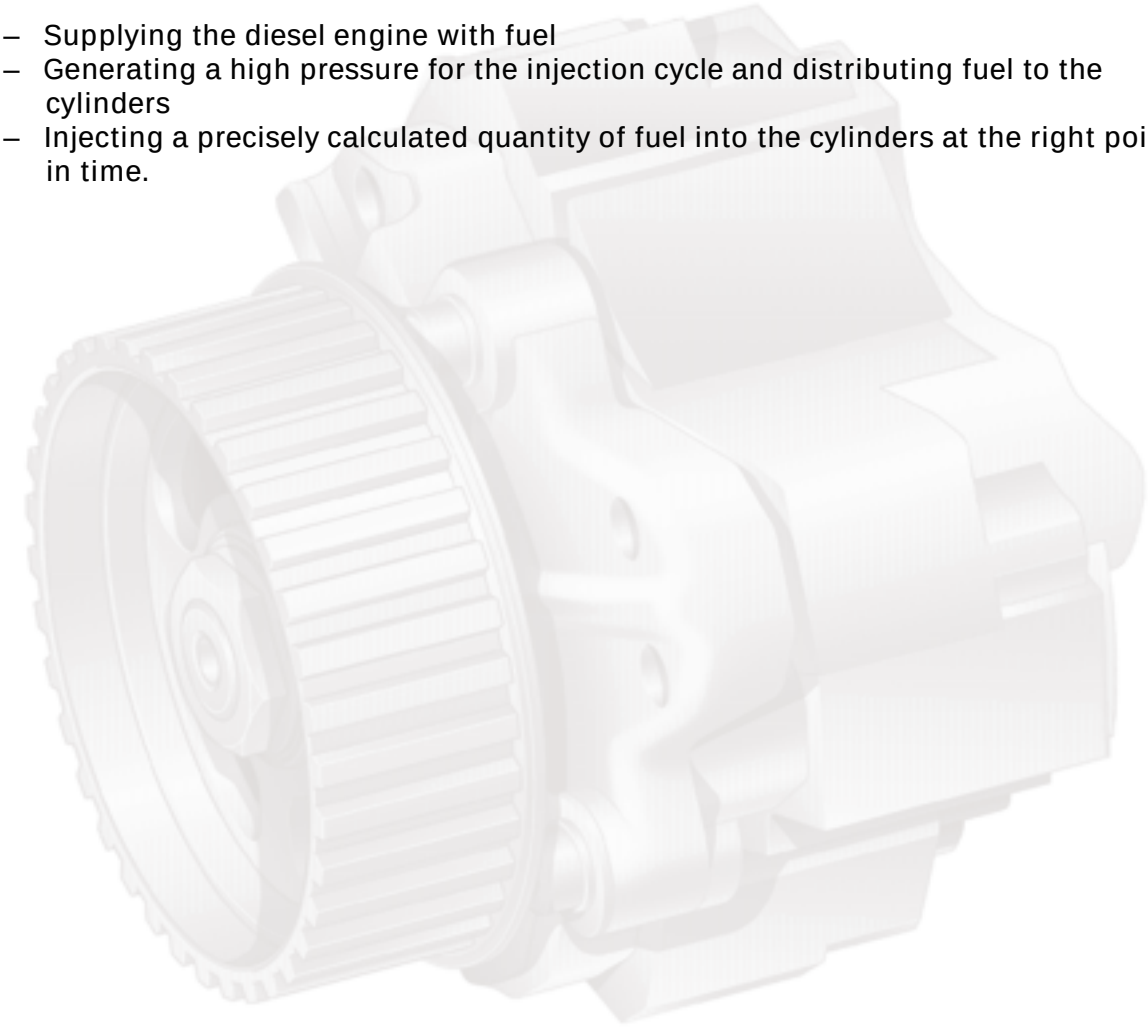
Common Rail

A new injection system for the V8 engine

Given that it can be integrated in existing engine concepts relatively easily, the common rail system is a new alternative injection system for modern diesel engines.

As with any injection system, the common rail serves the following tasks:

– Supplying the diesel engine with fuel
– Generating a high pressure for the injection cycle and distributing fuel to the cylinders
– Injecting a precisely calculated quantity of fuel into the cylinders at the right point in time.



Contents

The Self-Study Programme informs you about designs and functions.

The Self-Study Programme is not a Workshop Manual!

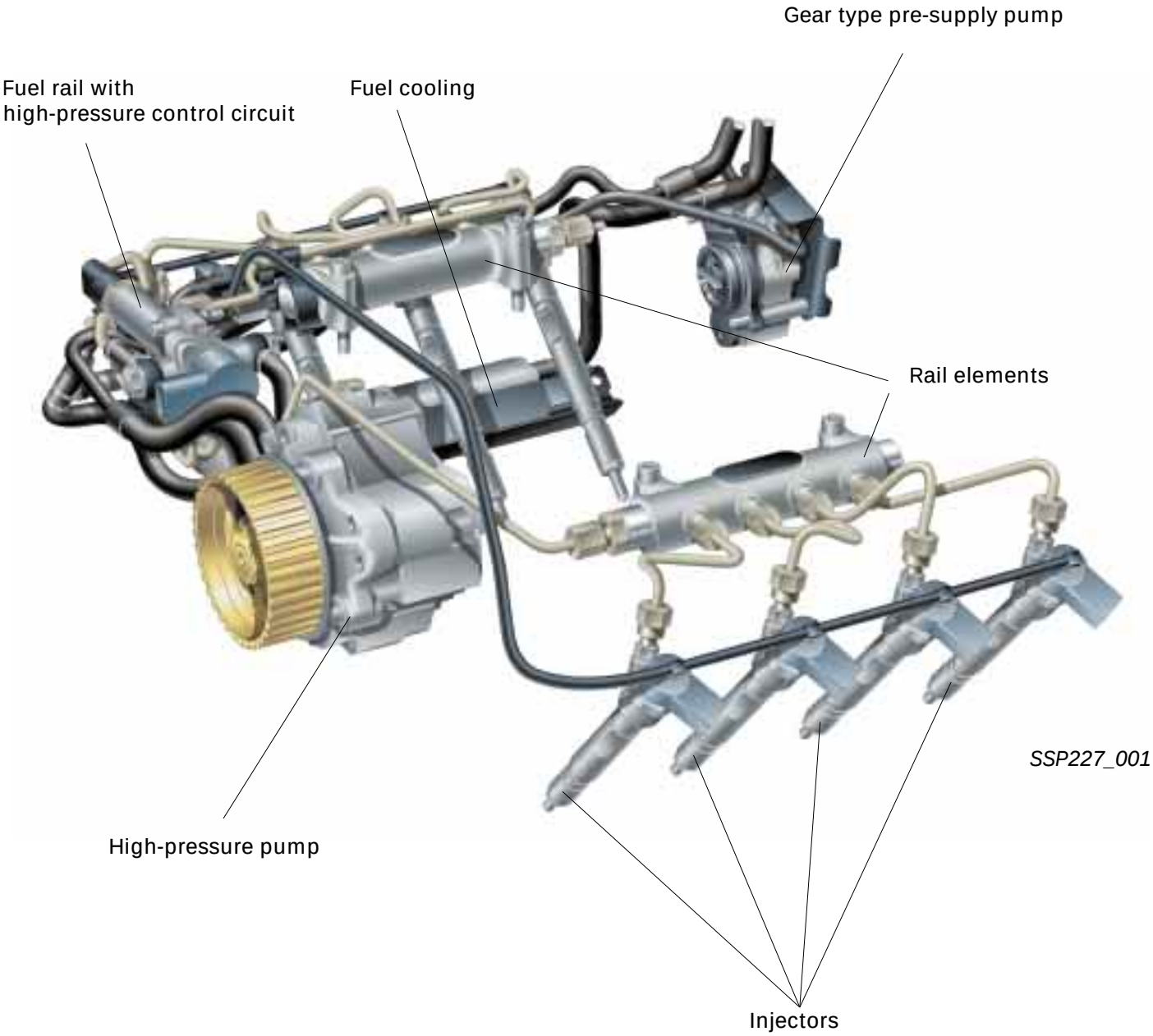
Please refer to the relevant Technical Literature for all maintenance and repair instructions.

Important!
Note!

Common Rail System

The common rail system comprises:

– The pre-supply pump
– The high-pressure pump
– The fuel rail with high-pressure control circuit and
– One rail element with 4 injectors per cylinder bank.



The Common Rail System is a pressure accumulator-type injection system.

In the Common Rail System, pressure generation and fuel injection take place separately.

A separate high-pressure pump housed in the inner V of the cylinder block generates pressure continuously.
This pressure is accumulated inside a rail and supplied to the injectors of a cylinder bank along short injection pipes.

The engine control unit controls the quantity of fuel injected into the cylinders and the injection timing by means of solenoid valves on the injectors.

Advantages:

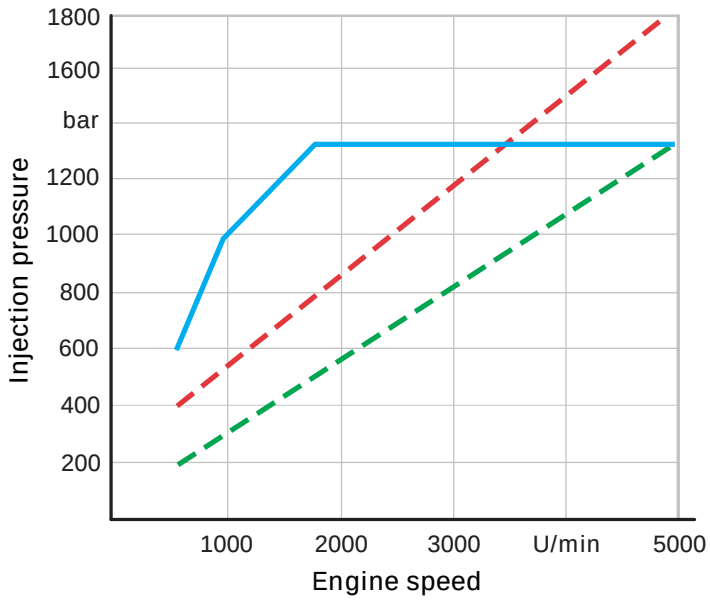
– The fuel injection pressure can be selected almost at random from a range of values within the characteristic zone

– High injection pressures are available at low revs and in the part-throttle range

– Flexible commencement of fuel injection with pre-injection cycle, main injection cycle and post-injection cycle

– There is much potential for development for future dieselcombustion processes given the total flexibility with regard to injection

– Exhaust-gas aftertreatment systems can be integrated optimally



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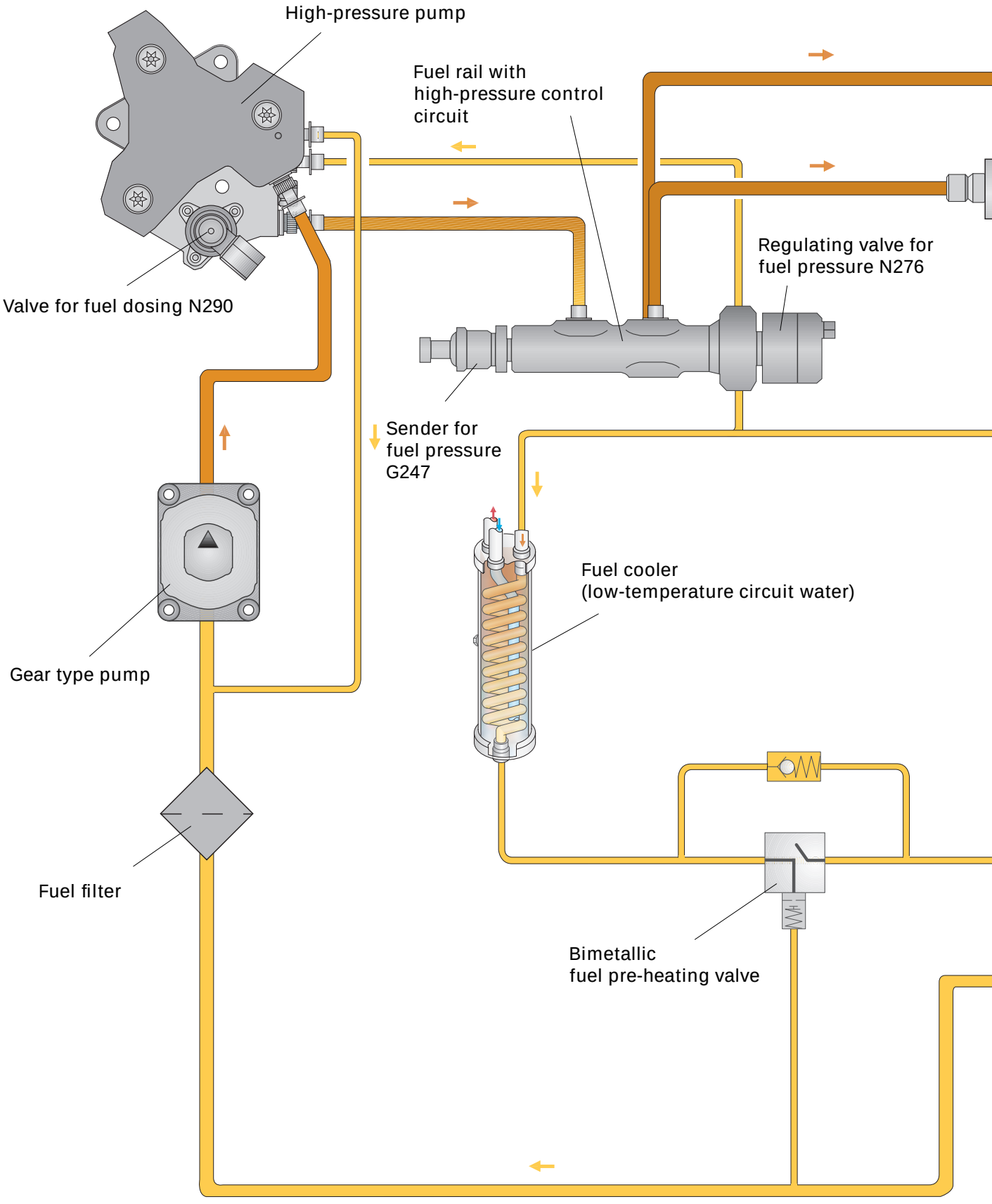
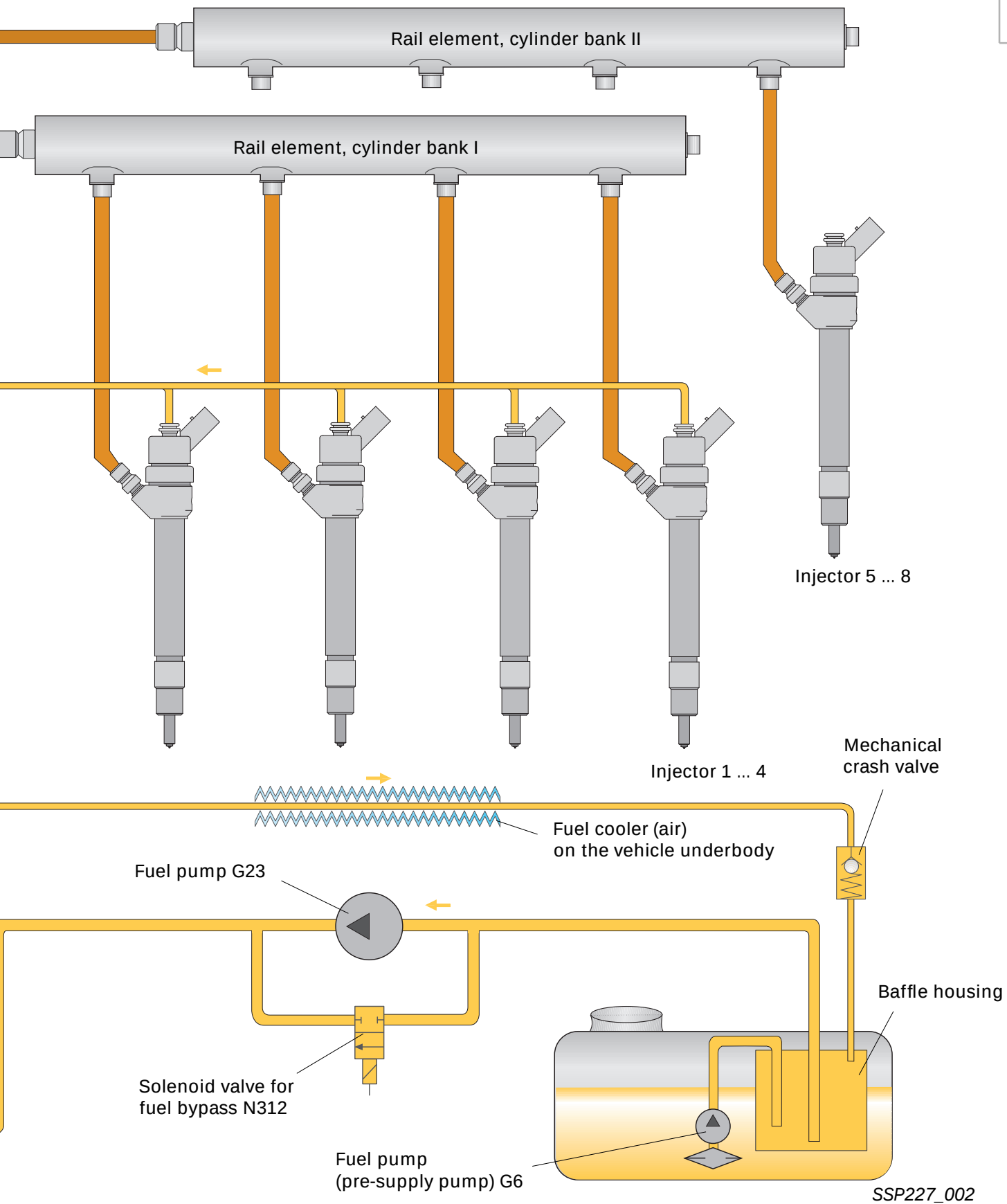
The common rail accumulator type injection system
Pump injector element
Other cam-driven systems

Components of the common rail

Fuel feed

Overview




Rail element, cylinder bank II
Rail element, cylinder bank I
Injector 5 ... 8
Injector 1 ... 4
Mechanical crash valve
Fuel cooler (air) on the vehicle underbody
Fuel pump G23
Baffle housing
Solenoid valve for fuel bypass N312
Fuel pump (pre-supply pump) G6

SSP227_002

Low-pressure feed

Roller cell pump (fuel pump G23)

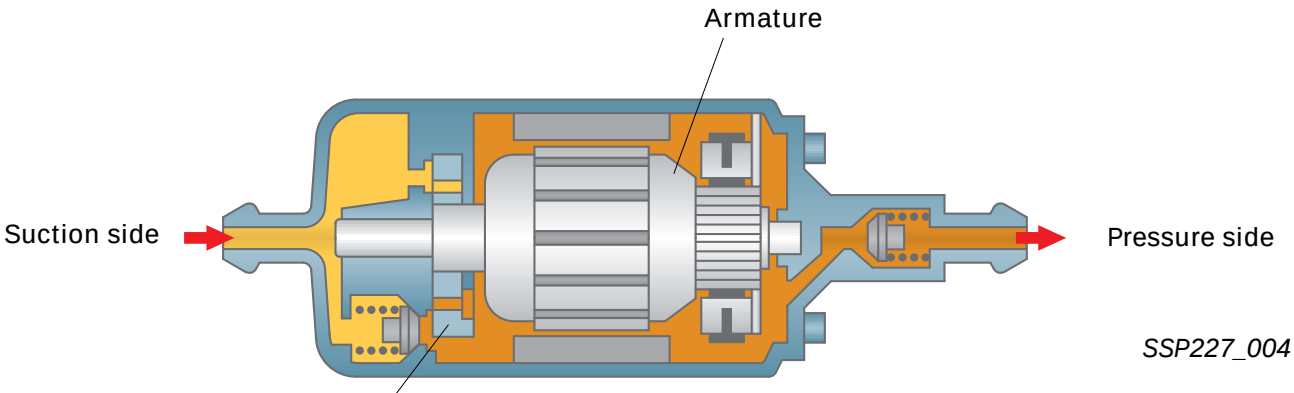
The roller cell pump (an electric pre-supply pump) is attached to the tank exterior at the right.

The pump runs when the starter is operated, drawing fuel out of the baffle housing.
Two suction jet pumps (entrainment pumps) driven by a pump located inside the fuel tank (pre-supply pump G6) fill the baffle housing with fuel.

The task of the roller cell pump is to supply fuel with a pilot pressure of approx. 3 bar to the gear-type pump whenever the engine is started.

This enables the engine to be started quickly at any fuel temperature.

The roller cell pump is shut down after the engine has been started.



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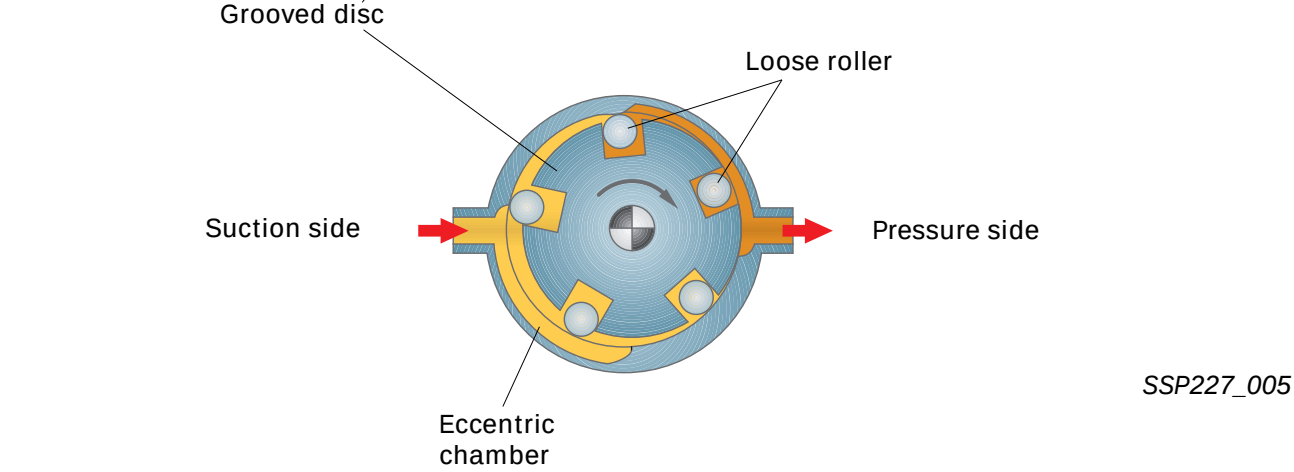

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Gear type pump

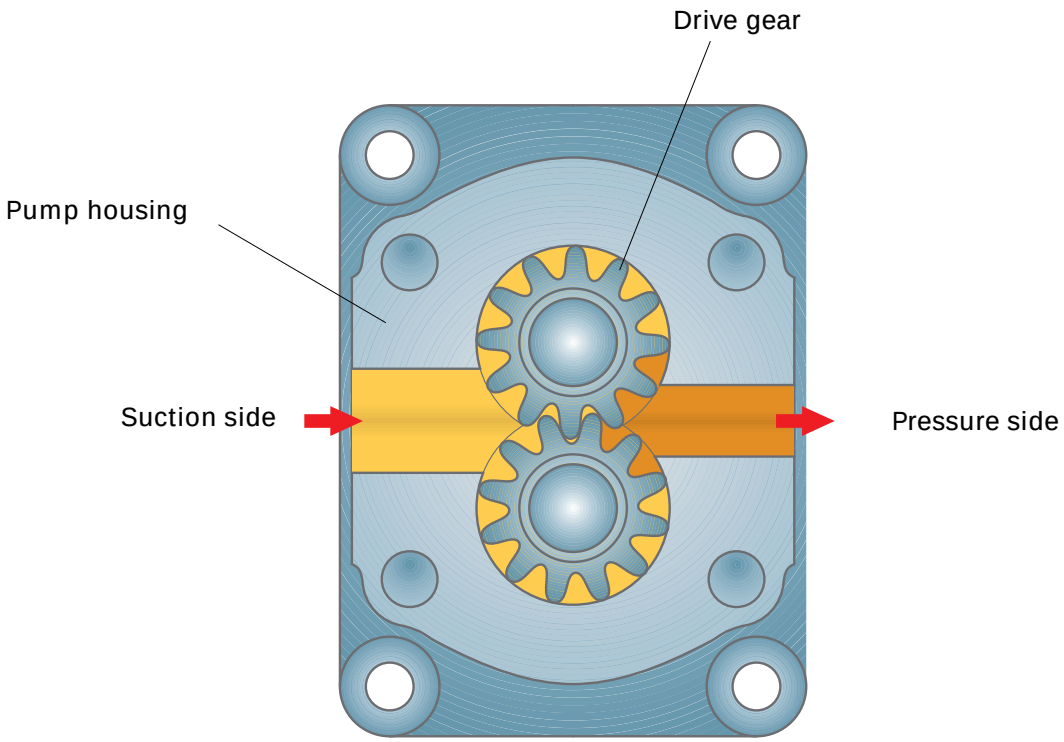
The gear type pump is a mechanical, self-priming pre-supply pump.
It is driven directly by the inlet camshaft of the right cylinder bank.

The gear type pump draws fuel out of the baffle housing and pumps it into the tank along a bypass duct (bypassing the roller cell pump) after the engine starts running.

The gear type pump, in turn, delivers fuel to the high-pressure pump.

Advantages of the mechanical gear type pump:
- Lower sensitivity to soiling (particle barrier)
- Reliability
- Service life
- Vibration resistance

Delivery rate	3.1 cm^3 /U		
Delivery rate	40 l/h	at	300 rpm
	120 l/h	at	2500 rpm



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High-pressure feed

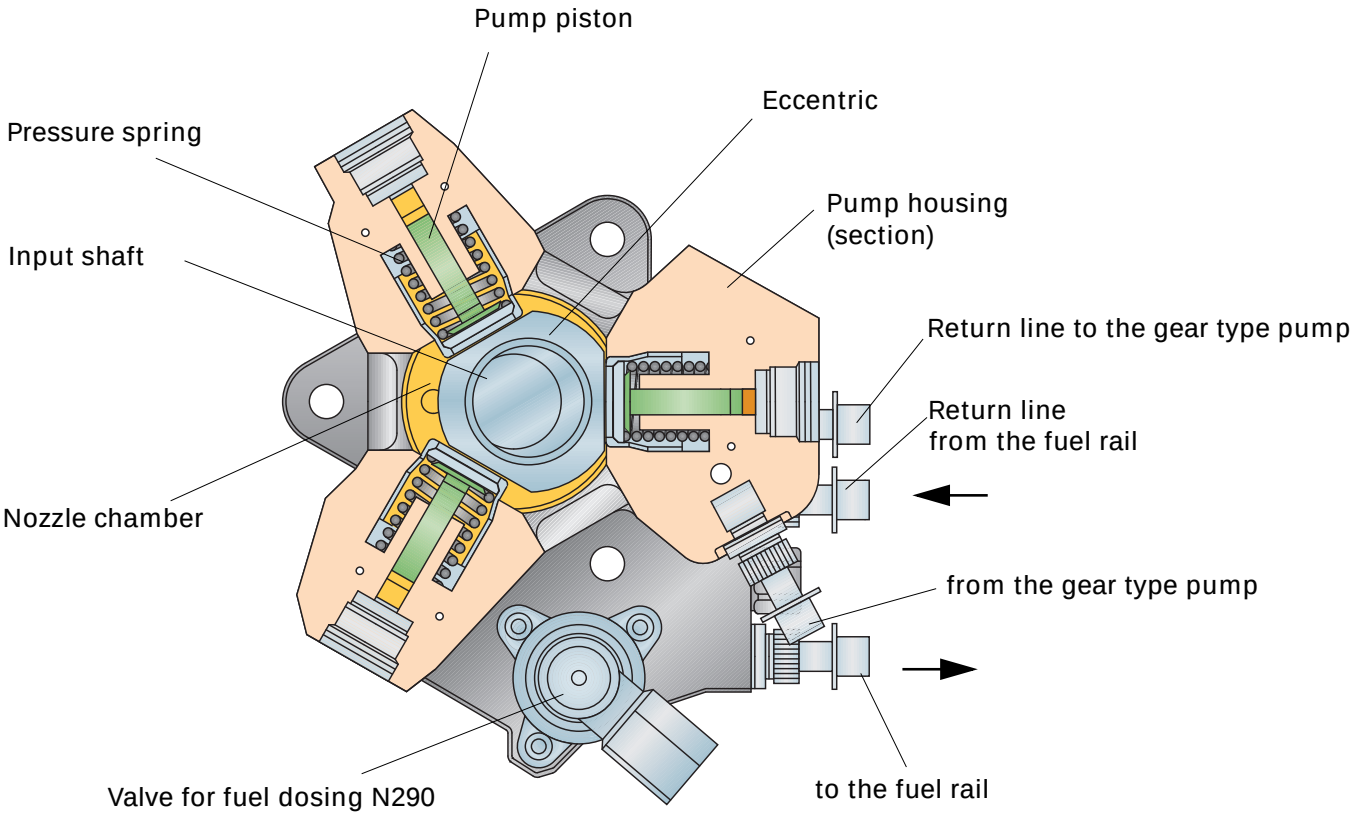
High-pressure pump

A 3-piston pump with a controlled intake restrictor in the inner V serves as a high-pressure pump.

The high pressure is generated by the radial piston pump with three
pump pistons arranged at an angle of 120°.
The radial piston pump is driven by means of a toothed belt.

Three feed strokes per revolution result in low peak torque and a even loading of the pump drive.

Max. torque demand is 17 Nm at 1300 bar. This is approx. 9 times less than that of comparable distributor pumps which utilise conventional injection technology.



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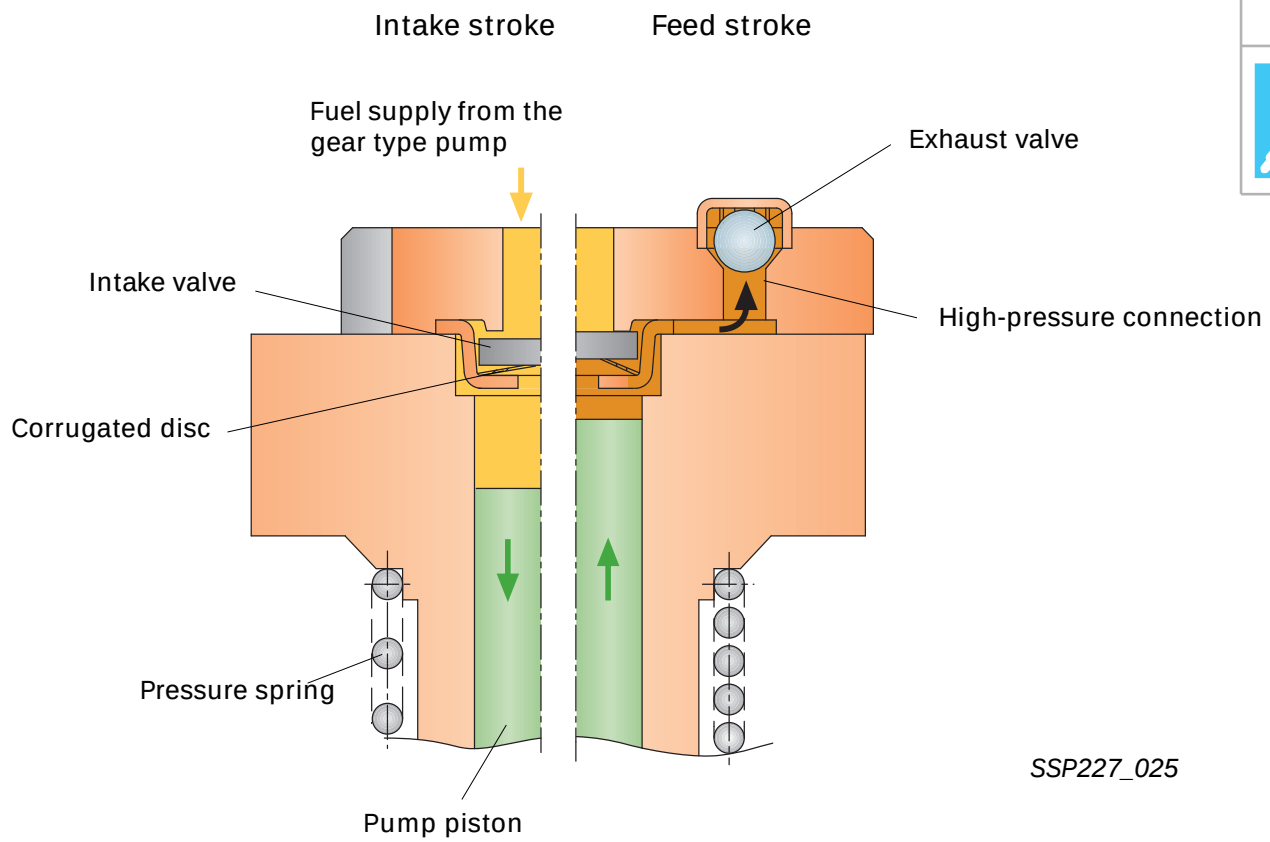
Specifications

Max. pressure	1350 bar
Rev range:	75 ... 3000 rpm
Delivery rate:	0.6 ... 0.7 cm^3/U
Power consumption:	3.5 kW at rated engine speed and at a rail pressure of 1350 bar



The input shaft, with its eccentric cam, moves the pistons of the three pump elements up and down in a sine-wave pattern.
The gear type pump forces fuel into the nozzle chamber or the lubricating and cooling circuit of the high-pressure pump through the restrictor bore of solenoid valve for fuel dosing N290.

If the fuel feed pressure exceeds the opening pressure of the safety valve (0.5 - 1.5 bar), the gear type pump can force fuel through the intake valves in the pump element thus causing the piston to move down (intake stroke).

If a piston overshoots bottom dead centre, the intake valve closes due to the pressure drop.

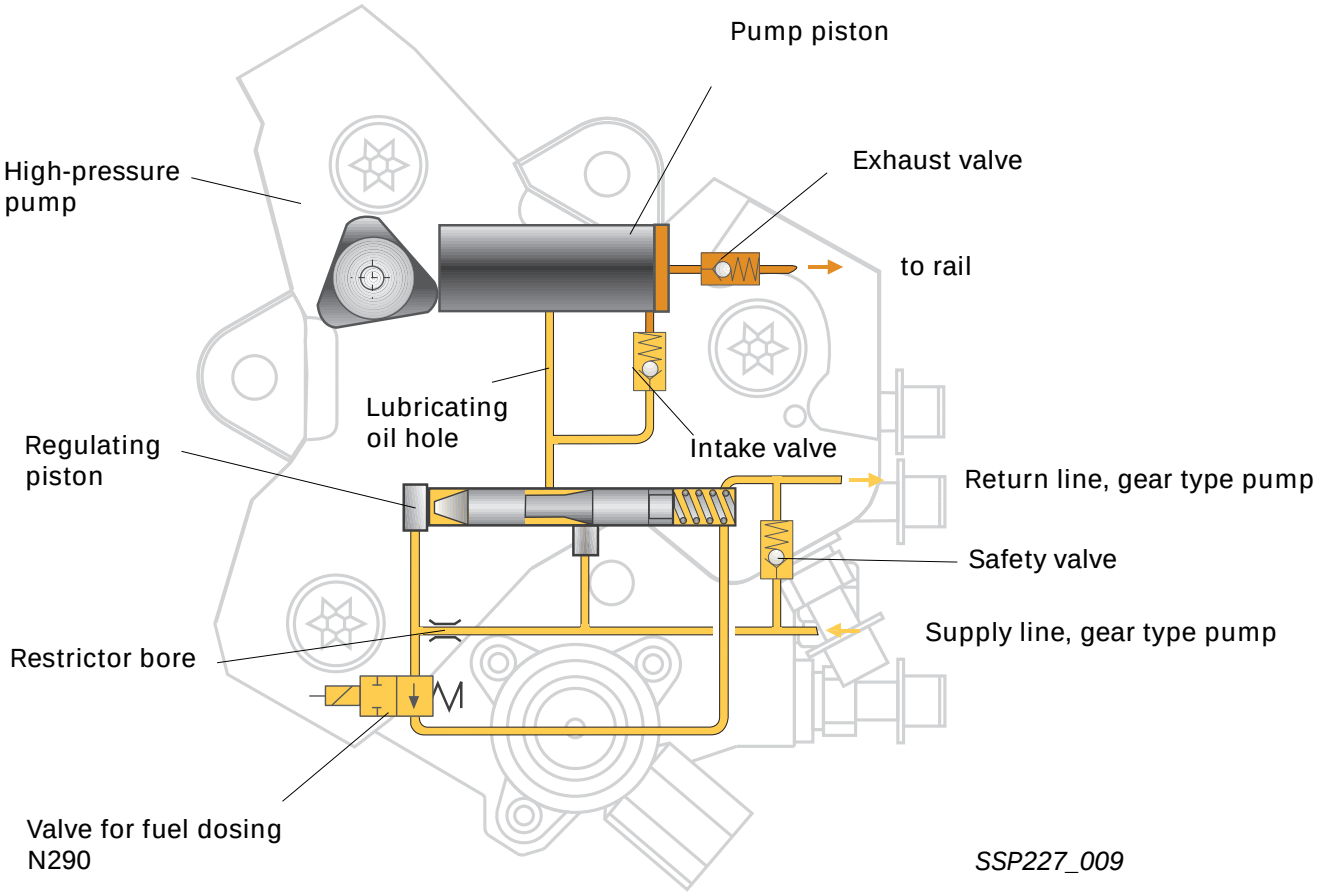
The fuel in the pump element can no longer escape.
The fuel can now be compressed beyond the feed pressure of the gear type pump.

The pressure which now builds up causes the exhaust valve to open once it exceeds the pressure present in the rail. The compressed fuel now enters the high-pressure circuit.

The pump element delivers fuel until top dead centre is reached (feed stroke).

Components of the common rail

Valve for fuel dosing N290



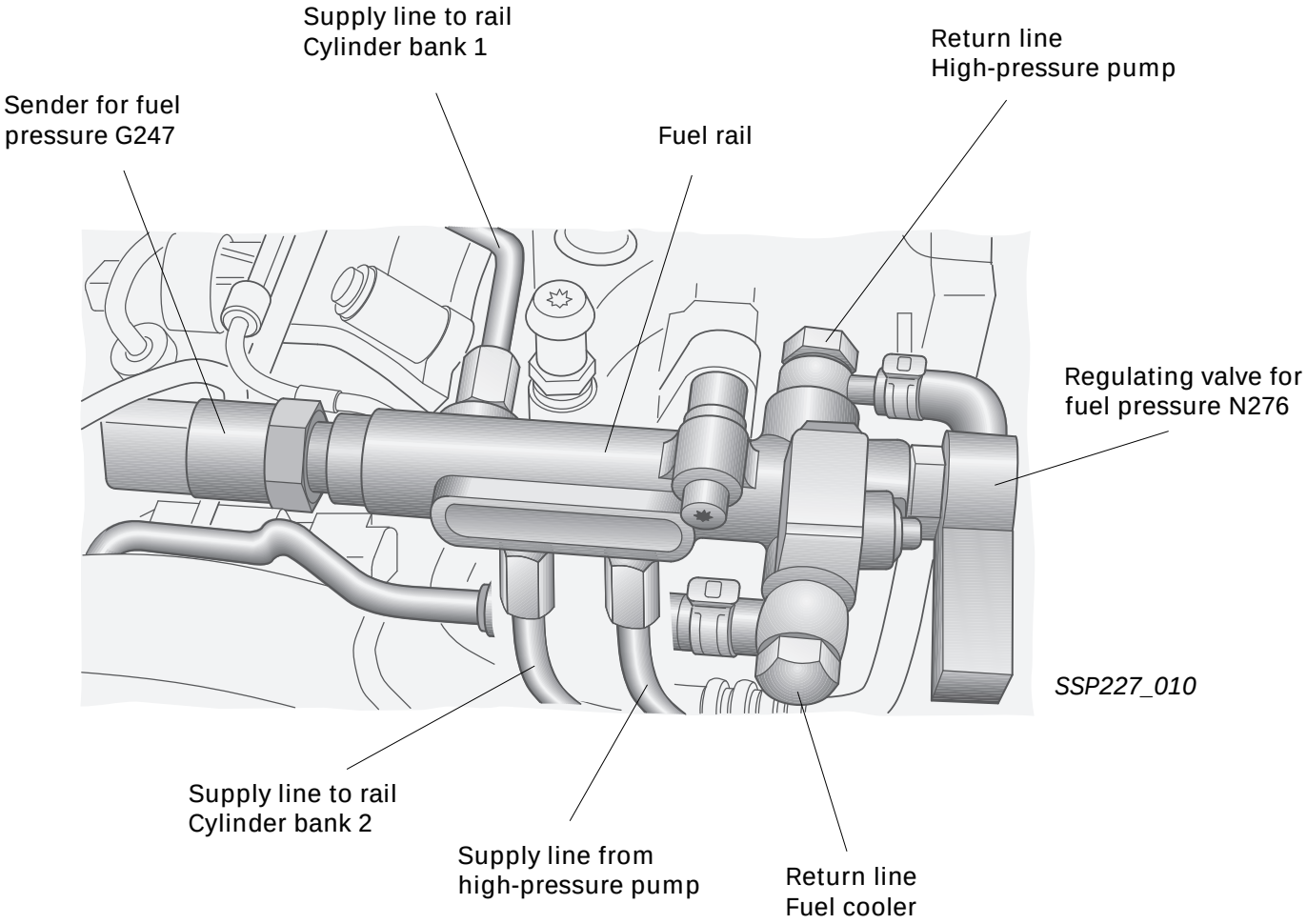
The high-pressure pump is driven by the toothed belt of the camshaft drive whose gear ratio in relation to engine speed is i=2/3. In the part-throttle range and at high engine speeds, the high-pressure pump can feed and compress more fuel than is injected into the cylinders.

To reduce the power consumption of the high-pressure pump and avoid unnecessary fuel heating at these operating points, fuel can be redirected to the fuel return line (inner circuit) by means of the solenoid valve N290.

Operated condition
of de-energised solenoid valve N 290
When it is de-energised, the solenoid valve is open. The control piston is pushed to the left by spring force and releases the minimum cross section to the high-pressure pump.
The solenoid valve is more or less closed depending on load and engine speed.

Operated condition
of activated solenoid valve N290
When it is activated, the solenoid valve is closed. The control pressure drops and the control piston restricts the feed to the high-pressure pump.
The control pressure and therefore the piston position are changed by varying the pulse duty ratio. The fuel cut off by the solenoid valve returns to the gear pump.

Fuel rail with high-pressure control circuit



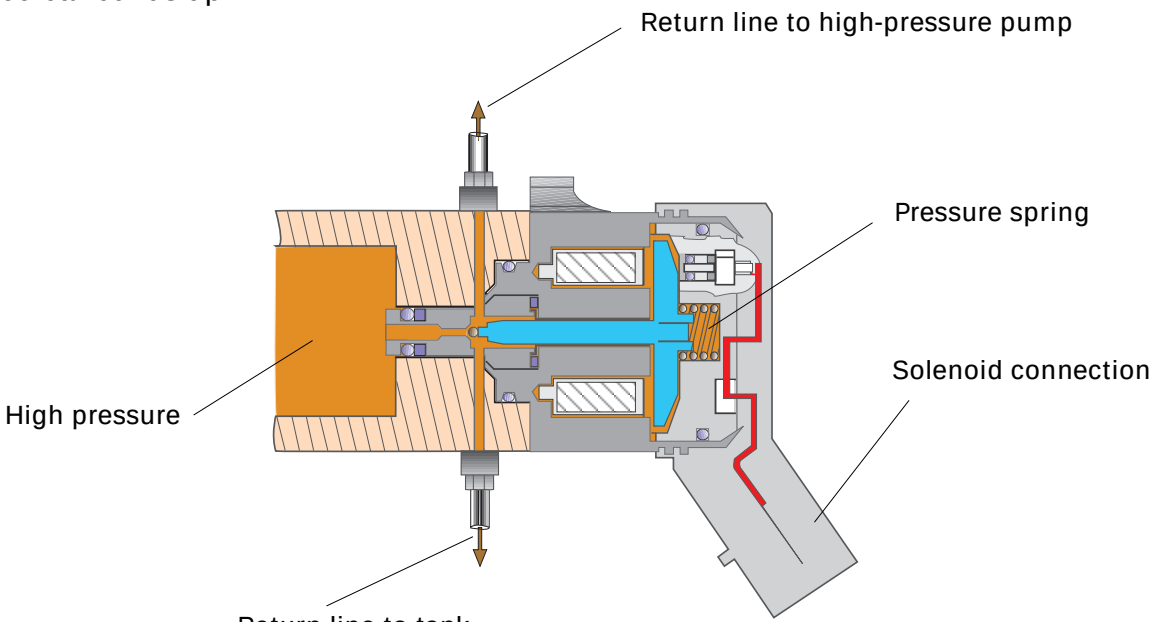
The fuel rail accommodates the fuel pressure sender and the electric control valve for fuel pressure, and distributes the fuel evenly to the two rails under a pressure of up to 1350 bar.

Components of the common rail

Regulating valve for fuel pressure N276

The regulating valve is located in the fuel rail and generates a defined pressure in the high-pressure circuit in dependence upon operating point.

Engine – "OFF“
In the resting position (valve de-energised), the force of the pressure spring counteracts the high pressure from the high-pressure pump. In the process, a rail pressure of approx. 100 bar builds up.



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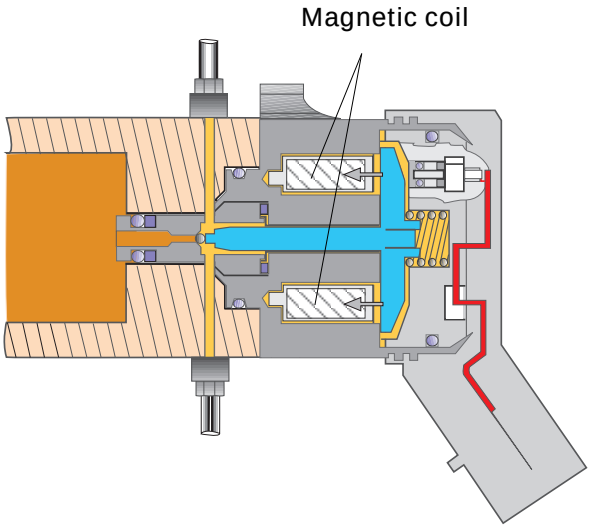
Engine – "ON"
To increase the rail pressure, a magnetic force is opposed to the high pressure of the high-pressure pump by applying an electric current to the magnetic coil.

The flow cross-section and the redirected quantity are reduced as a result. This allows the rail pressure to be set optimally by the control unit and pressure fluctuation in the rail to be compensated.

The fuel quantity redirected at the pressure regulating valve returns to the tank along the return line.



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Sender for fuel pressure G247

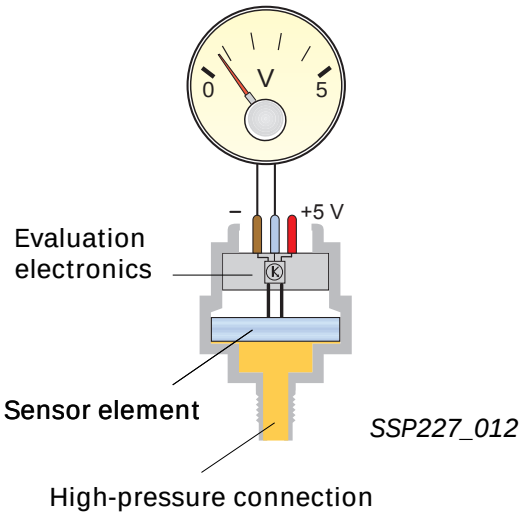
The fuel pressure sender measures the current pressure in the high pressure system.

The sensor element records this pressure and sends a corresponding voltage signal to the engine control unit through the evaluation electronics.

The supply voltage to the evaluation electronics is 5 V.

The resistance drops as the pressure increases, causing the signal voltage to rise.

The high-precision sender for fuel pressure is the chief component in the system.



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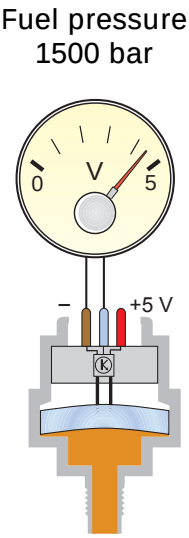
If the fuel pressure sender fails, a fixed value is utilised for activating the regulating valve for fuel pressure, i.e. the system enters the emergency running mode.



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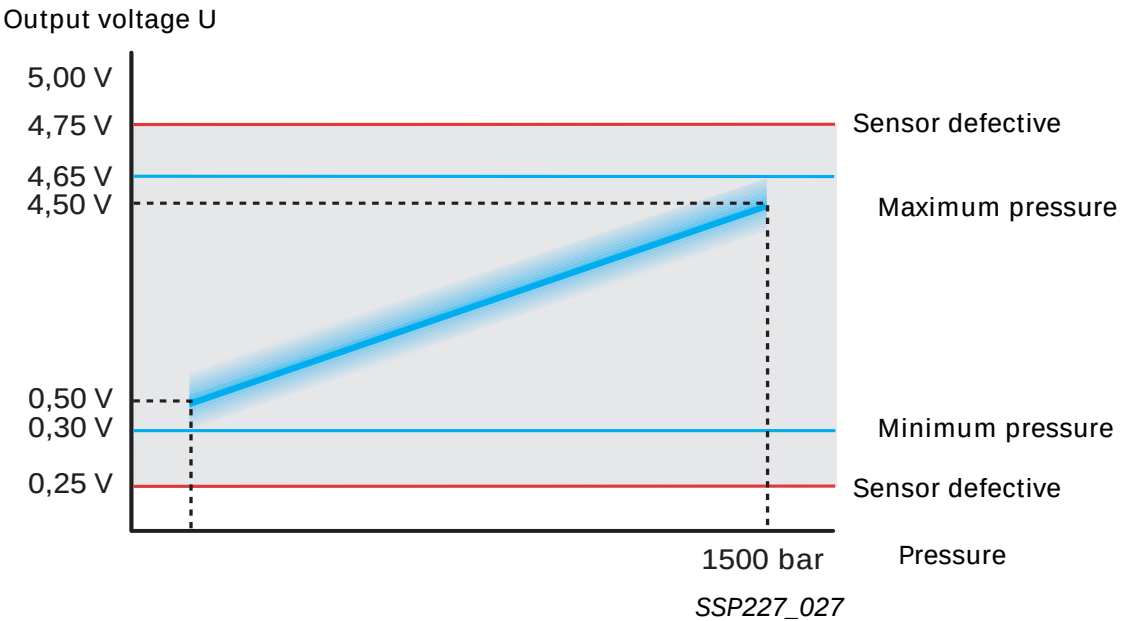

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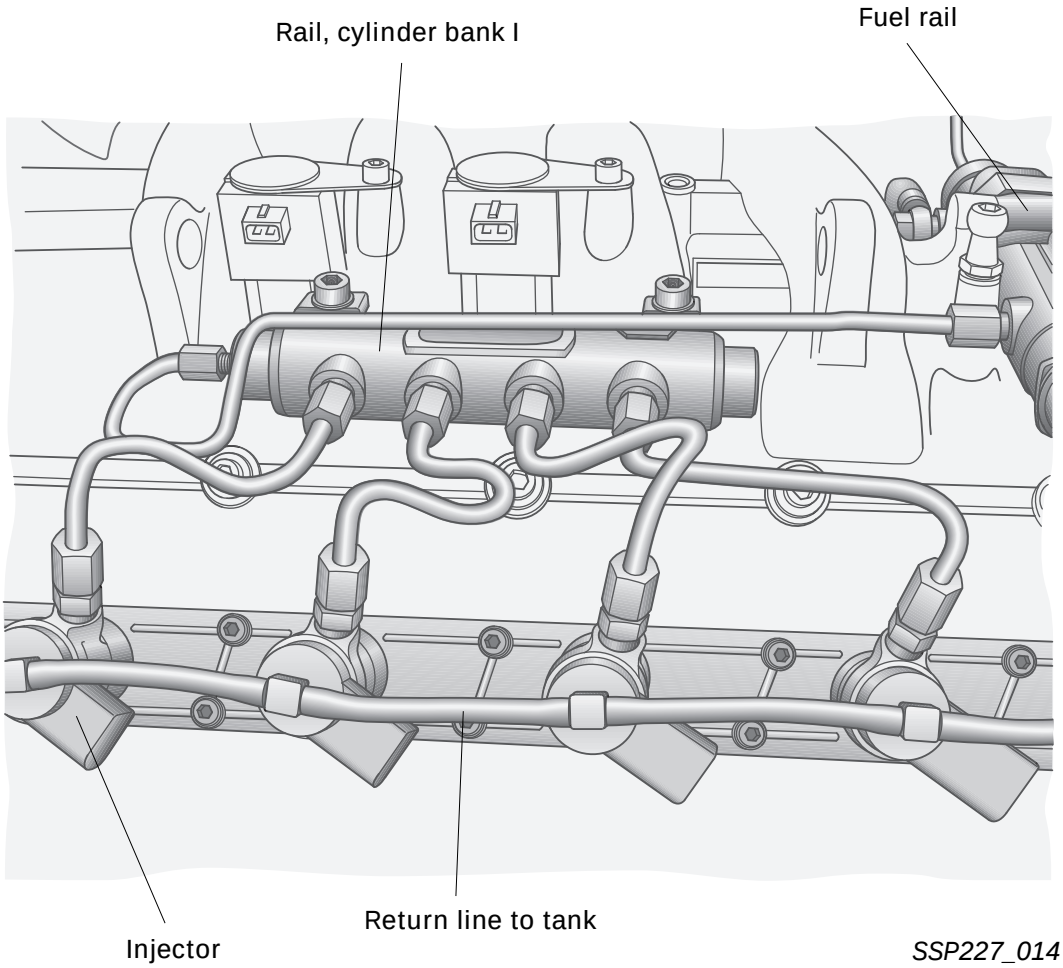
Components of the common rail

High-pressure circuit

The high-pressure circuit comprises the high-pressure pump, the fuel rail with regulating valve for fuel pressure, the two rails for cylinder banks I+II, as well as the individual high-pressure pipes to the injectors.

The accumulated volume of fuel acts as a damper on pressure oscillation caused by the high-pressure pump and simultaneous short-time withdrawal of fuel during the injection cycle.



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Valve-controlled injection unit (injector)

Components of the injector:

– six-hole nozzle with injector needle
– hydraulic timing system
– solenoid valve
– and fuel ducts

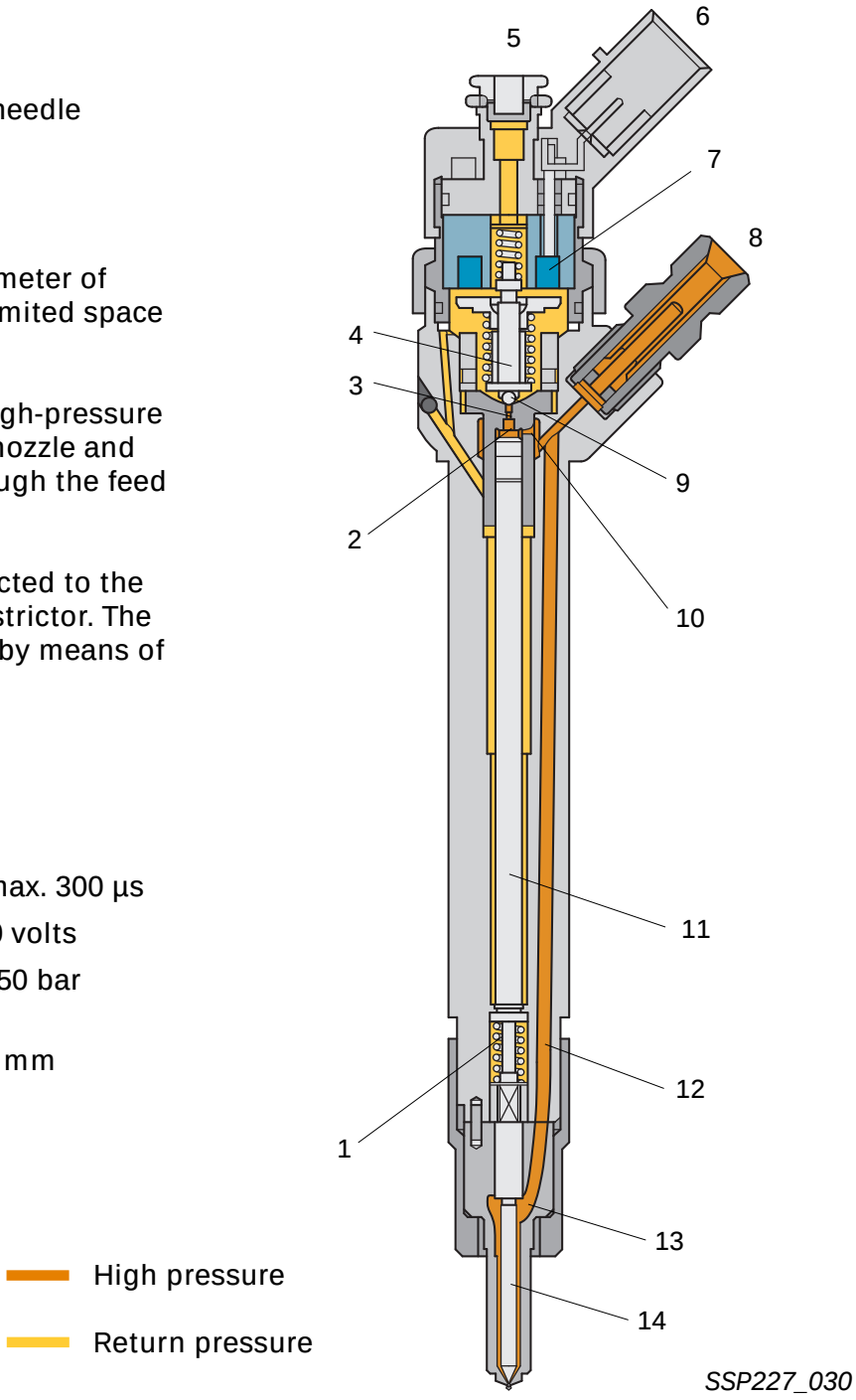
Very narrow injectors with a diameter of 17 mm are used in view of the limited space available in the cylinder head.

The fuel is conveyed from the high-pressure connection along a duct to the nozzle and into the valve timing space through the feed restrictor.

The valve timing space is connected to the fuel return line via the return restrictor. The return restrictor can be opened by means of a solenoid valve.

Specifications

Pick-up current	> 20 A max. 300 µs
Activation	up to 80 volts
Pressure range1	20 ... 1350 bar
Dia. of injection holes in nozzle	6 x 0.15 mm



1 – Injector spring
2 – Valve timing space
3 – Return restrictor
4 – Solenoid valve armature
5 – Fuel return line (to tank)
6 – Electrical connection, solenoid valve
7 – Solenoid valve
8 – Fuel supply - high pressure from rail
9 – Valve ball
10 – Feed restrictor
11 – Valve timing piston
12 – Nozzle intake duct
13 – Chamber volume
14 – Injector needle

Components of the common rail

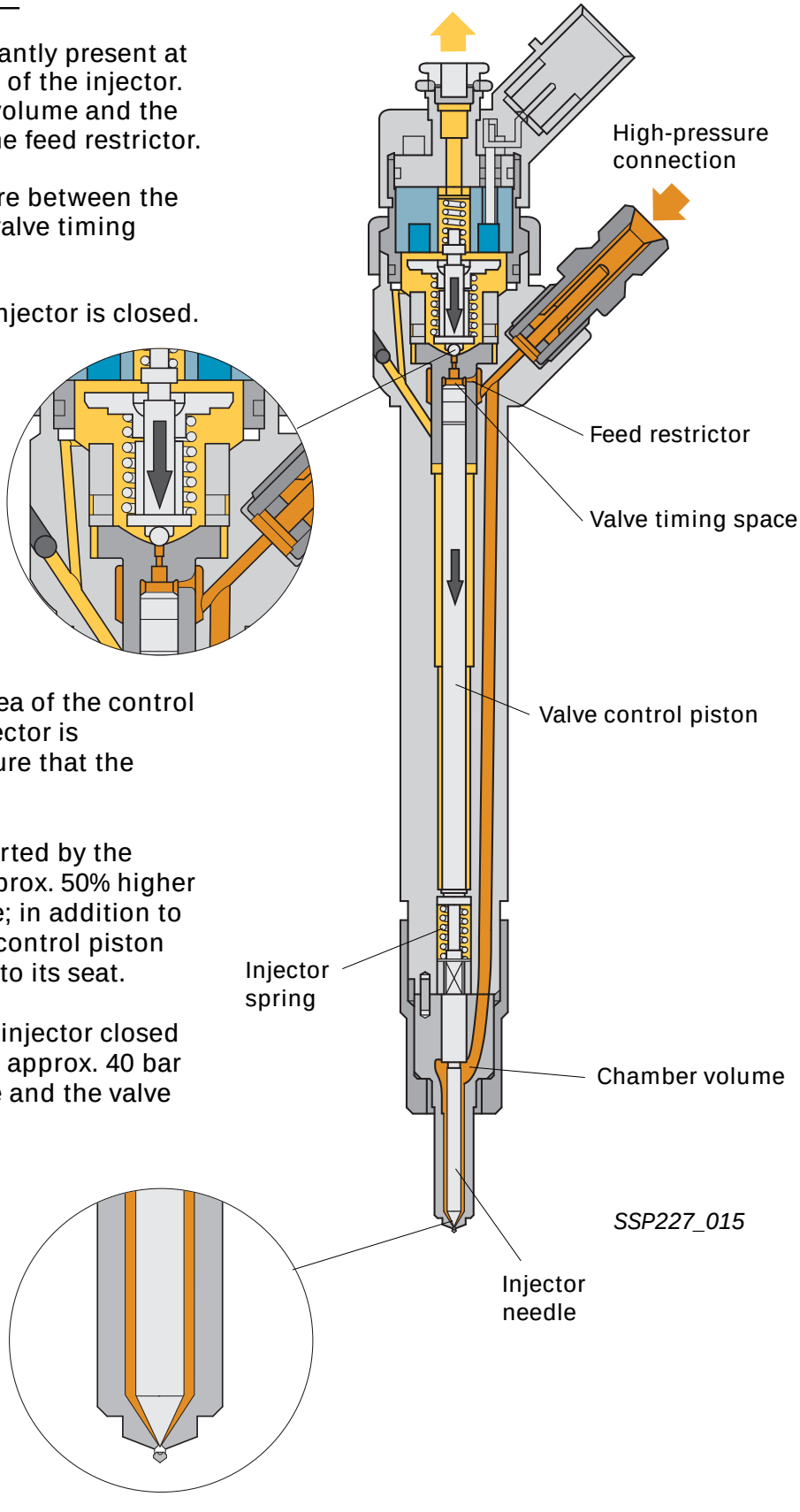
Function injector

Resting position - engine "OFF“

The fuel from the rail is constantly present at the high-pressure connection of the injector. The fuel floods the chamber volume and the valve timing space through the feed restrictor.

– There is a constant pressure between the chamber volume and the valve timing space.

– The solenoid valve of the injector is closed.



A pressure of 1.5 times the area of the control piston facing towards the injector is generated in order to make sure that the injector is leak-tight.

This means that the force exerted by the hydraulic control piston is approx. 50% higher than the nozzle opening force; in addition to the injector spring, the valve control piston presses the injector needle into its seat.

The injector spring keeps the injector closed up to a pressure difference of approx. 40 bar between the chamber volume and the valve timing space.

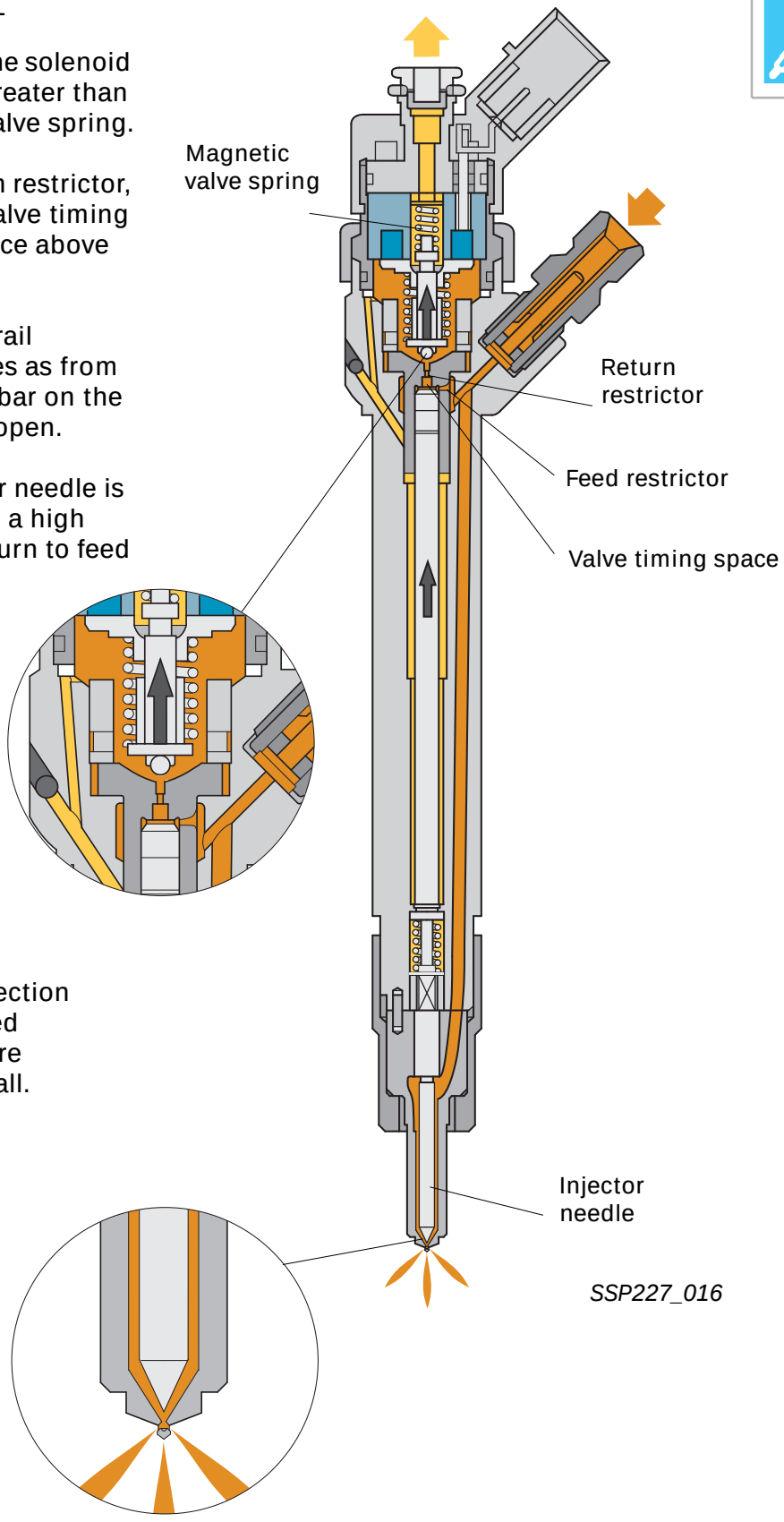
Start of fuel injection - engine "ON"

If an electric current is applied to the solenoid valve, the magnetic force will be greater than the closing force of the solenoid valve spring.

The solenoid valve opens the return restrictor, relieving the fuel pressure in the valve timing space and reducing the closing force above the nozzle.

As a result, the excess fuel and/or rail pressure below the nozzle increases as from an excess pressure of approx. 160 bar on the nozzle side, causing the nozzle to open.

The opening velocity of the injector needle is dependent upon the application of a high current for a short time and the return to feed restrictor cross-section ratio.



The return restrictor cross-section must be greater than the feed restrictor cross-section before injector needle can open at all.

Mixture formation

Commencement of fuel injection

If current is applied to the solenoid valve for longer, the valve control piston and injector needle will rise up to the control piston stop.

The nozzle is now open as far as it will go, and fuel is injected into the cylinders under approximately the same pressure as in the rail.

The solenoid valve opens completely during each injection cycle, even if only a very small quantity of fuel is to be injected.

To inject a small quantity of fuel, the solenoid valve is only energised (clocked) for a short period to time. The injector needle is not opened as far as it will go, it is only raised slightly.

The quantity of fuel injected into the cylinders is defined by:

– solenoid valve activation time
– needle opening and closing velocity
– needle lift
– hydraulic flow rate of nozzle
– rail pressure

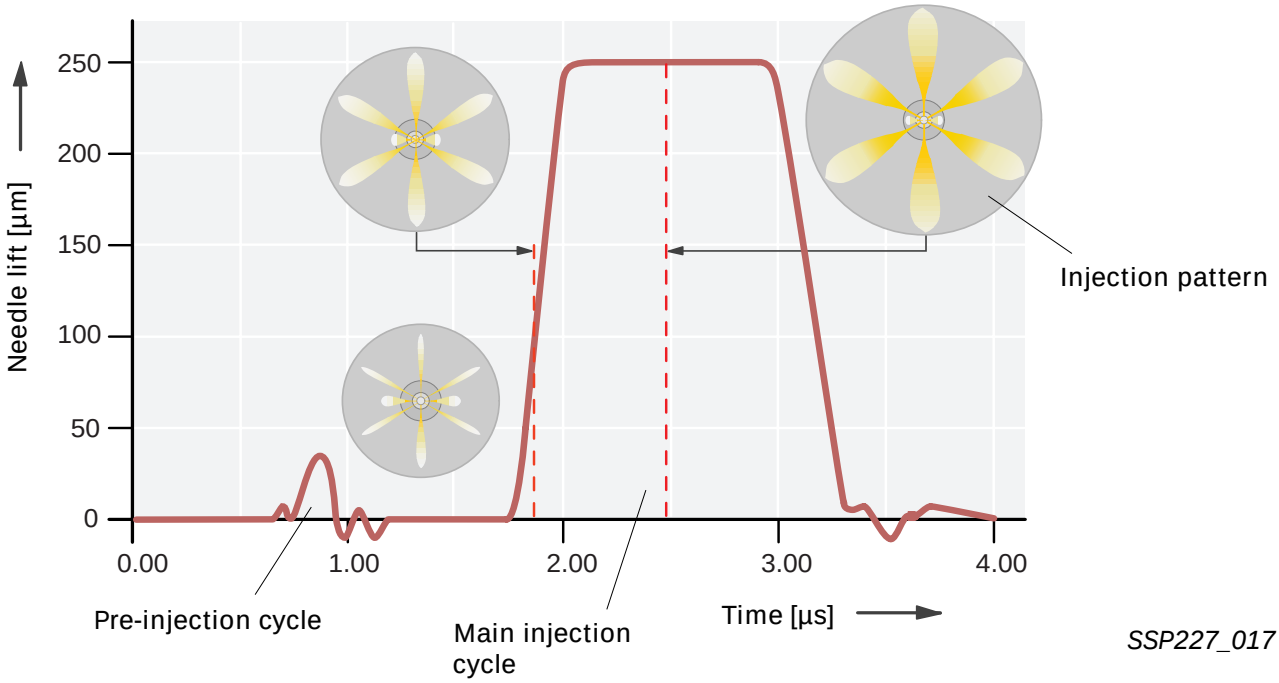
End of injection

If the solenoid valve is de-energised, the valve spring again presses the solenoid valve armature or the valve ball down onto the valve seat.

The return restrictor is closed and the pressure in the control space rises to system pressure. The closing force acting upon the nozzle above the control piston is greater than the opening force of the nozzle applied to the seat. This causes the injector to close.

In contrast to previous injection systems, injector closure is controlled even if the system pressure is very high (sharp end of injection drop).

Pre-injection cycle



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The object of the pre-injection cycle is to reduce combustion noise, exhaust emissions and fuel consumption.

The pre-injected quantity of fuel prepares the combustion chamber for the main quantity to be injected with respect to pressure and temperature for the main injection quantity.

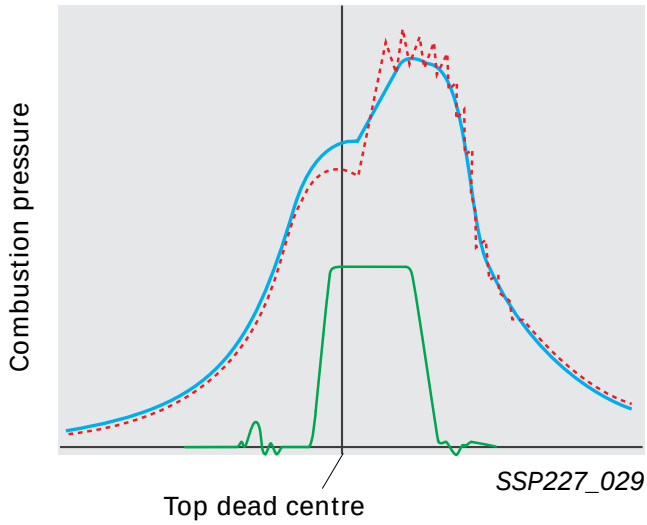
The main injection quantity is injected into the prechamber.

Advantage:

– The spark lag for the main injection cycle is shortened.
– This system produces less noise than conventional diesel engines thanks to the reduced combustion pressure peaks.
– Optimal combustion of the fuel mixture takes place.

The pre-injection cycle controls the combustion pressure curve by means of the following variable:

– Pre-injection quantity
– Distance to main injection cycle at increasing engine rpm



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Pressure curve with pre-injection cycle

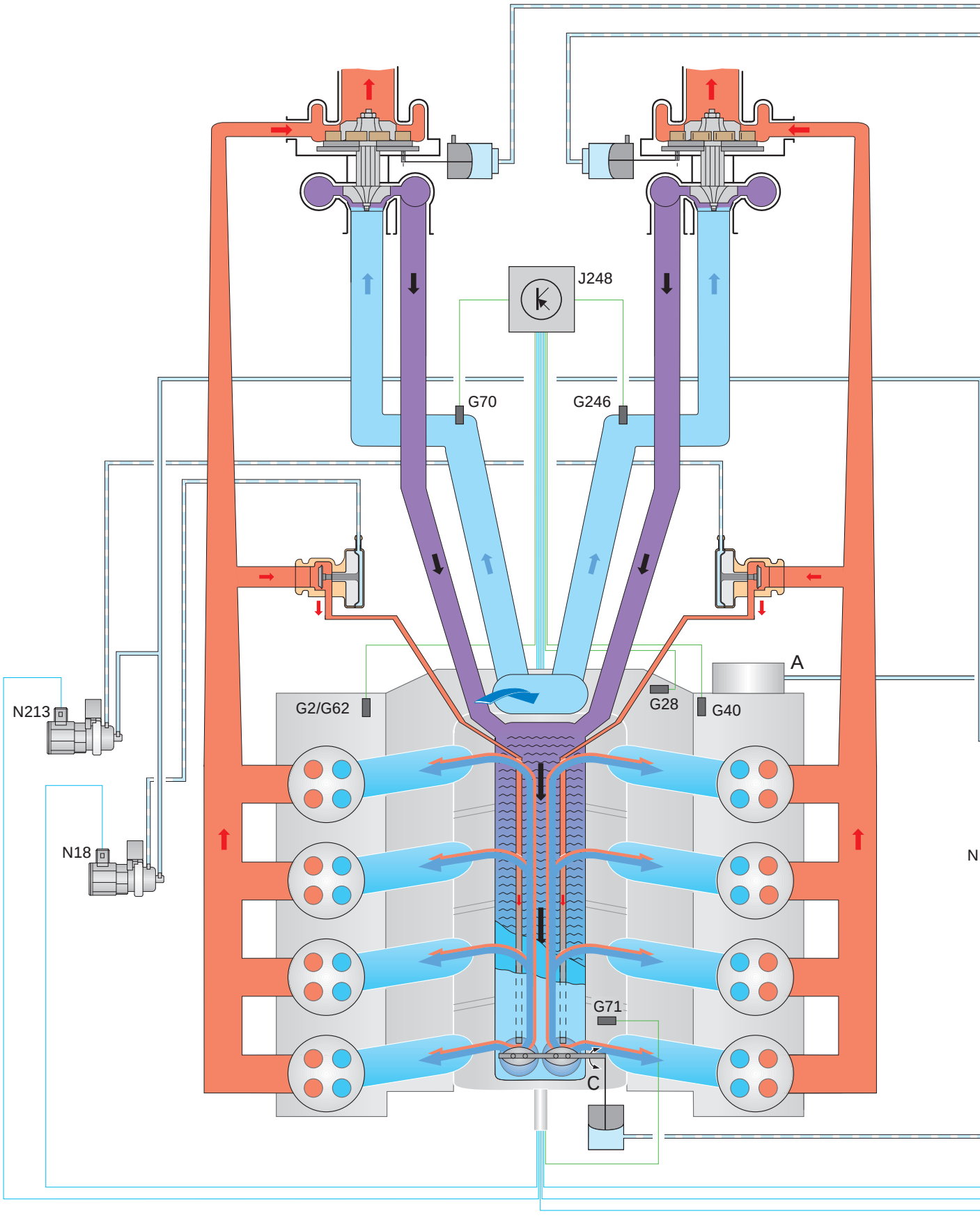
Pressure curve without pre-injection cycle

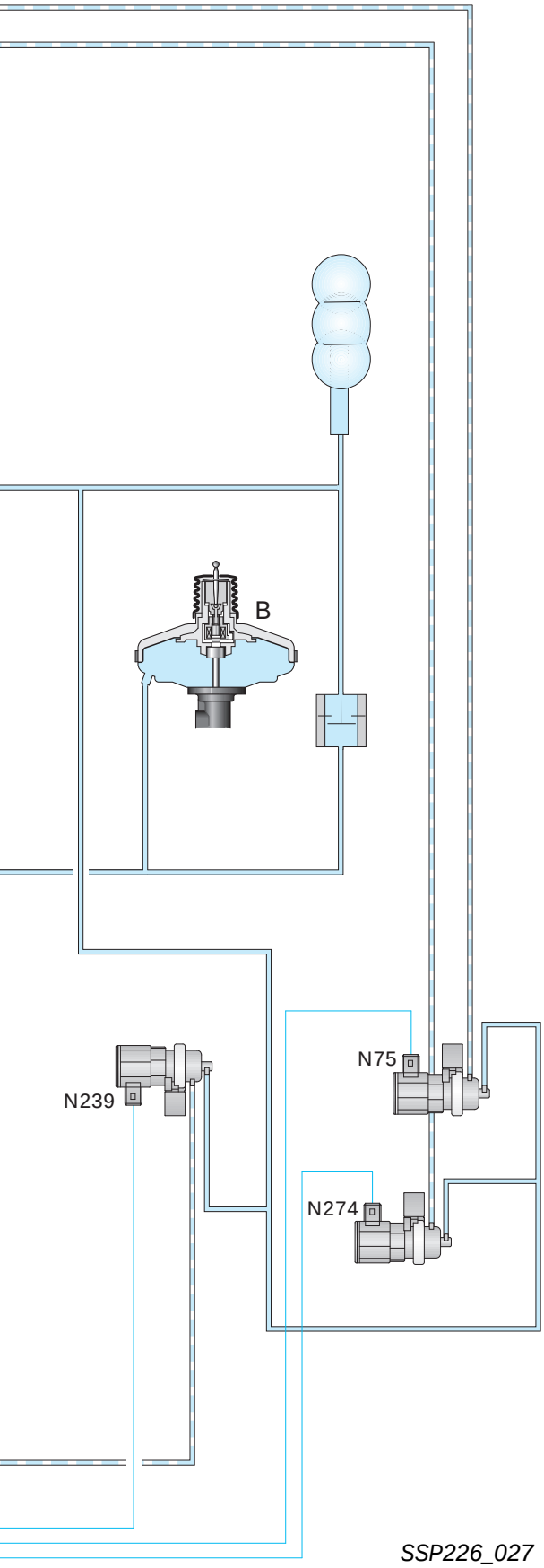
Needle lift curve

The figure shows the difference between the pressure curves of a combustion process with and without a pre-injection cycle.

Engine management

Vacuum control





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A	Vacuum pump
B	Brake servo
C	Throttle valve
G2/G60	Coolant temperature sender
G28	Engine speed sender
G40	Hall sender
G70	Air-mass flow meter
G71	Intake manifold pressure sender
G246	Air-mass flow meter 2
J248	Diesel direct injection system Control unit
N18	EGR valve Cylinder bank 1
N75	Charge pressure control solenoid valve
N213	Exhaust gas recirculation valve -2-
N274	Solenoid valve 2 for charge pressure control
N239	Intake manifold flap change-over valve

In the V8 TDI engine, an engine-driven vacuum pump (A) supplies a sufficient quantity of medium required for vacuum control.

In addition to the brake servo (B), the vacuum controls the exhaust gas turbocharger, the EGR valve and the two throttle valves (C) in the intake module.

Charge pressure data is acquired via the intake manifold pressure sender (G71). The signals from the two hot-film air mass meters (G70/G246) are utilised for controlling the turbocharger via the charge pressure limiting valves (N75, N274).

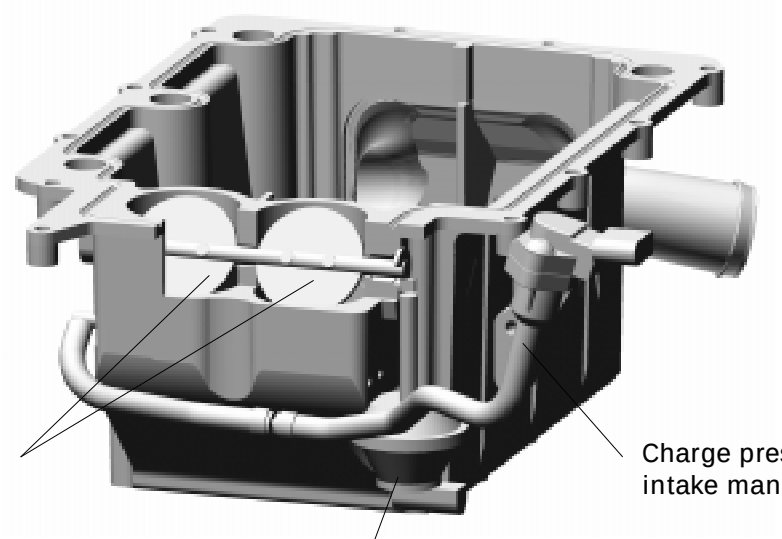
The throttle valves (C), activated by intake manifold flap change-over valve N239, are in operation when the engine is shut down for a short time.

Double-flow throttle valve

The double-flow throttle valve is closed when the engine is shut down for a short time.

Advantages:

The engine does not run on after it has been shut down and no unburned fuel enters the cylinders (when the engine is restarted, fewer unburned particles are emitted).



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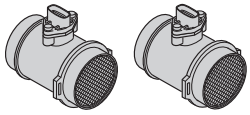
The two throttle valves are fully open in the rest and full-throttle positions.

Notes

System overview

Sensors

Hot-film air mass meter G70/G246



Engine speed sender G28

Coolant temperature sender G2 and G62

Sender for oil temperature G8

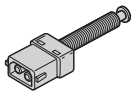
Fuel temperature sender G81

Sender for fuel pressure G247

Intake manifold pressure sender G71

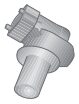
Accelerator pedal sender with accelerator position sender G79 and idling speed switch F60

Brake light switch F and Brake pedal switch F47

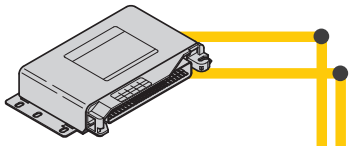


Kick-down switch F8

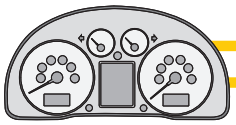
Hall sender G40



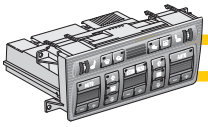
Auxiliary signals:
Cruise control system
Coolant temperature sender
DF signal
Terminal 50
Speed sensor signal
Crash signal from airbag control unit
High pressure sensor G65
A/C ready
Auxiliary heater coolant



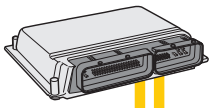
Automatic gearbox control unit J217



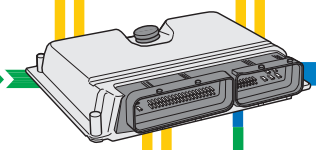
Combination processor in the dash panel insert J218



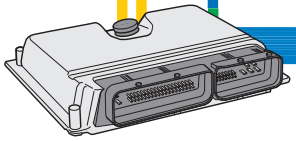
Operating and display unit for air conditioning system E82



ESP control unit J104

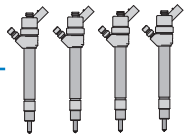


Diesel direct injection system control unit J248



Control unit 2 for diesel direct injection system J494

Actuators



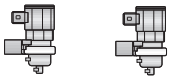
Solenoid valve for injector, cylinders 5-8; N83 – N86

Glow plug relay J52
Glow plugs 1-4; Q6

Relay 2 for glow plugs J495
Glow plugs 5-8; Q6

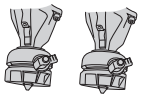
Intake manifold flap change-over valve N239

Regulating valve for fuel pressure N276



EGR valves 1 + 2; N18 + N213

Solenoid valve for fan control N313

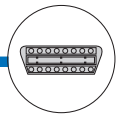


Electro/hydraulic engine mounting left/ right, solenoid; N14427/N145

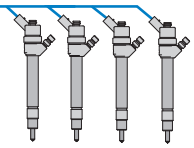
Charge pressure control solenoid valves 1+ 2; N75/N274

Relay for pump charge air cooling J536
Pump for charge air cooling V188

Electric fuel pump II relay J49
Fuel pump G23



Diagnostic connection



Solenoid valve for injector, cylinders 1-4; N30 – N33

Fuel bypass valve N312

Valve for fuel dosing N290

Fuel pump relay J17
Fuel pump (pre-supply pump) G6

Pump relay, fuel cooling J445
Pump for cooling fuel V166

Alternator cut-in relay J442

Auxiliary signals:

Air conditioner compressor
Auxiliary heater, coolant

Auxiliary signals:

Fan speeds 1+2

Function diagram

Code codes

= Input signal

= Positive

= Bidirectional

= Output signal

= Earth

= CAN-BUS

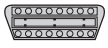
Components

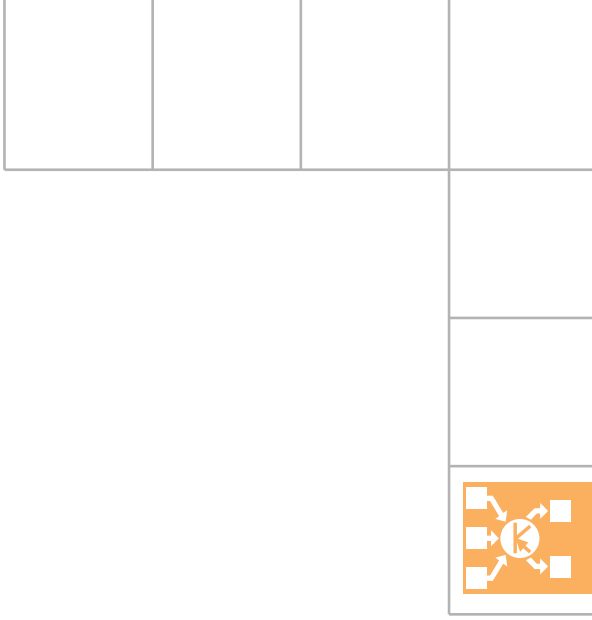
A	Battery
E45	Cruise control system switch
D	Ignition switch
F	Brake light switch
F8	Kick-down switch
F47	Brake pedal switch for cruise control system
F60	Idling speed switch
G2	Coolant temperature sender
G6	Fuel pump (pre-supply pump)
G8	Oil temperature sender
G23	Fuel pump
G28	Engine speed sender
G40	Hall sender
G62	Coolant temperature sender
G70	Air-mass flow meter
G71	Intake manifold pressure sender
G79	Accelerator position sender
G81	Fuel temperature sender
G246	Air-mass flow meter
G247	Fuel pressure sender
J17	Fuel pump relay
J49	Electric fuel pump II relay
J52	Glow plug relay
J248	Diesel direct injection system control unit
J317	Voltage supply relay Terminal 30
J442	Alternator cut-in relay
J445	Pump relay, fuel cooling
J494	Diesel direct injection system control unit
J495	Glow plug 2 relay
J536	Pump relay, charge air cooling
M9	Brake light bulb, left
M10	Brake light bulb, right
N18	EGR valve
N30	Solenoid valve for injector, cylinder 1
N31	Solenoid valve for injector, cylinder 2
N32	Solenoid valve for injector, cylinder 3
N33	Solenoid valve for injector, cylinder 4
N75	Solenoid valve for charge pressure control
N83	Solenoid valve for injector, cylinder 5
N84	Solenoid valve for injector, cylinder 6
N85	Solenoid valve for injector, cylinder 7
N86	Solenoid valve for injector, cylinder 8
N144	Electro/hydraulic engine mounting left, solenoid
N145	Electro/hydraulic engine mounting right, solenoid
N213	Exhaust gas recirculation valve -2-
N239	Intake manifold flap change-over valve
N274	Solenoid valve 2 for charge pressure control
N276	Regulating valve for fuel pressure
N290	Valve for fuel dosing
N312	Fuel bypass valve
N313	Solenoid valve for fan control
Q6	Glow plug
S	Fuse
ST	Fuse carrier
S204	Fuse, terminal 30
V166	Pump for cooling fuel
V188	Pump for charge air cooling

1	Fan speed
2	2nd fan speed
3	Terminal 61, alternator
4	Coolant temperature
5	Sensor earth
6	Speed sensor signal
7	Terminal 50
8	DF signal
9	Crash signal from airbag control unit
10	Additional heater, coolant
11	Additional heater, coolant
12	High pressure sensor G65
13	A/C ready
14	Air-conditioner compressor signal
15	Terminal 30a

CAN-BUS L
CAN-BUS H } Connection to databus

X Y Z... Terminals within the function diagram

 Diagnostic connection (K-wire)



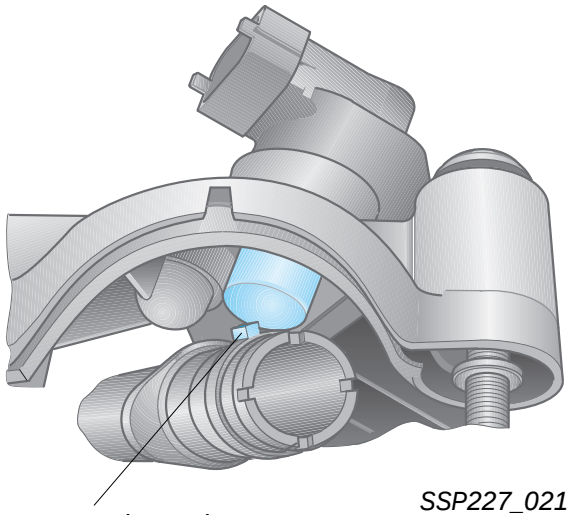
Actuators and sensors

Hall sender G40

The inlet camshaft of the second cylinder bank has a ferro-magnetic tooth.

When the tooth passes by the phase sensor, a voltage signal (Hall voltage) is generated for a short time.

The camshaft signal is generated once per revolution of the camshaft and indicates the position of the 1st cylinder to the master control unit in the compression phase.

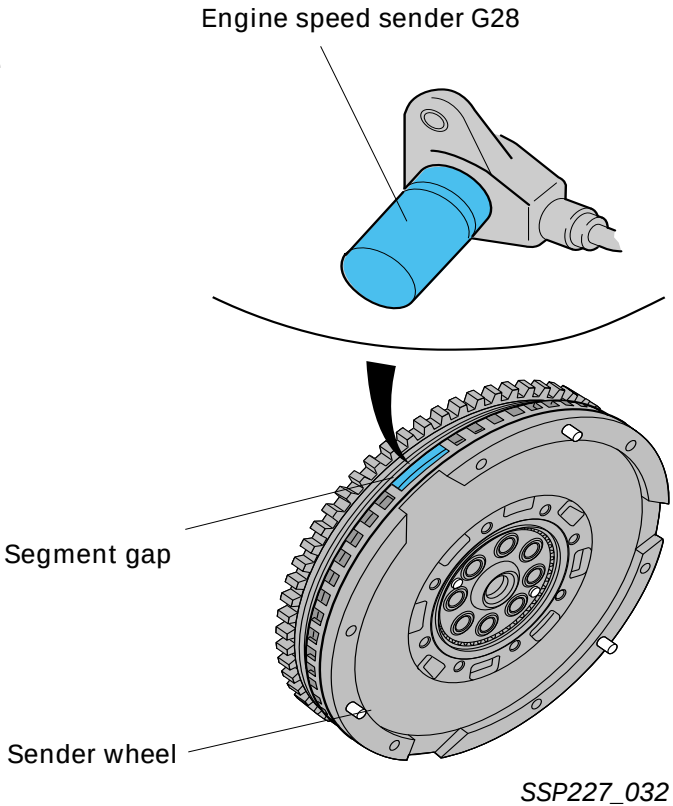


SSP227_021

Engine speed sender G28

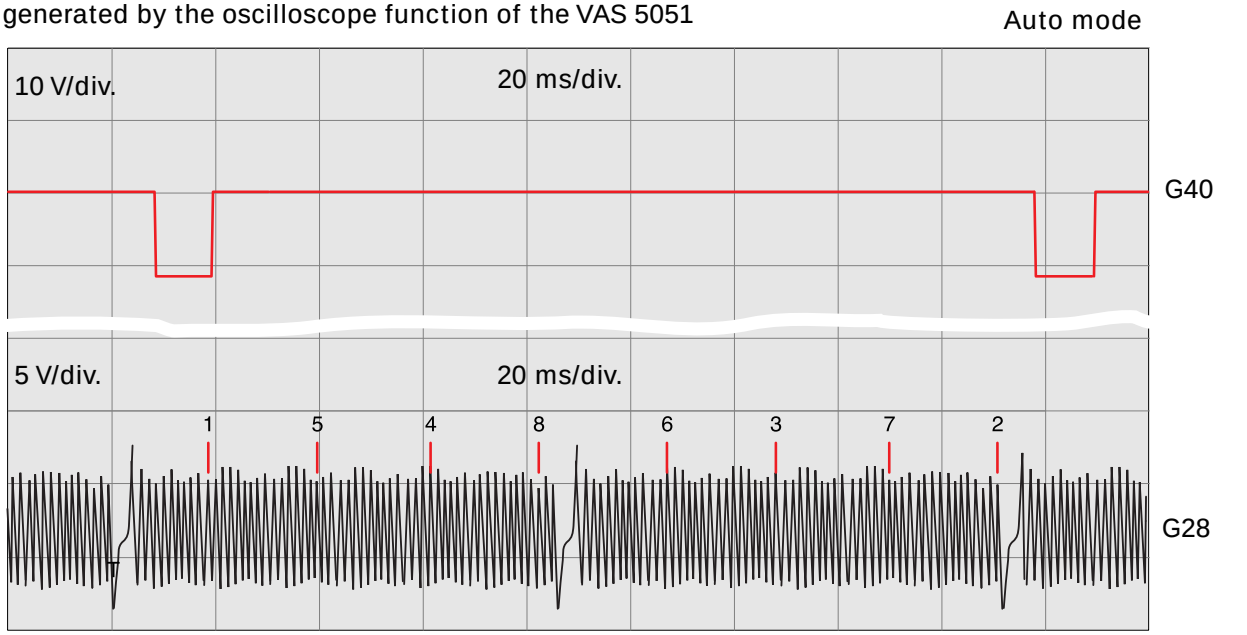
The engine speed sender is an inductive sender. It acquires engine speed data and the exact angular position of the crankshaft.

If the engine speed sender fails, engine operation will not be possible.



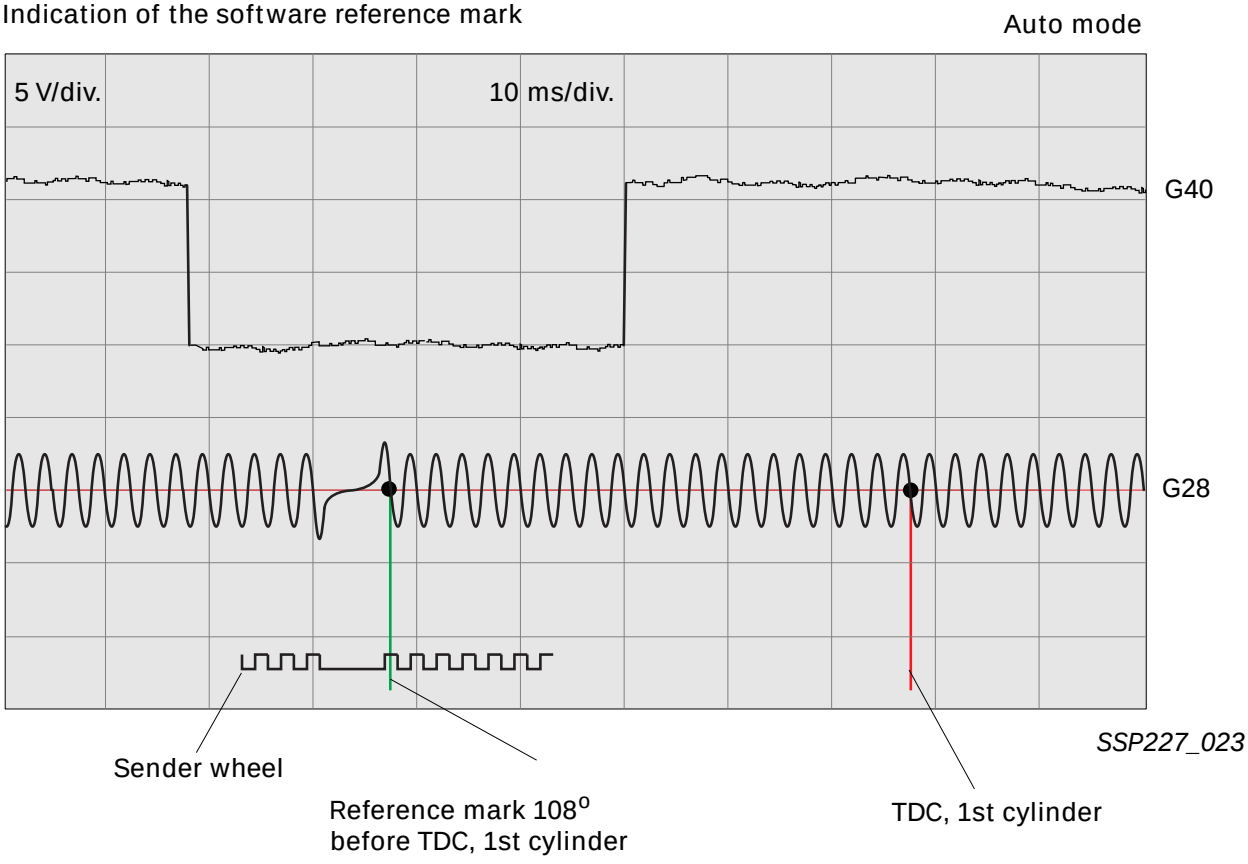
SSP227_032

Signal pattern from engine speed sender G28 and Hall sender G40 as generated by the oscilloscope function of the VAS 5051



SSP227_022

Indication of the software reference mark



SSP227_023

The reference mark is the point at which the control unit sets the crank angle to 0 (initialisation).

This reference mark is located approx. 108° crank angle before ignition TDC of the 1st cylinder.

Engine management

Engine control unit J248/J494

In the V8 TDI, two engine control units, one master control unit and one slave (auxiliary) control unit are responsible for engine management.

The master control unit performs all the functions which are required to calculate and control parameters, e.g. injection point and injection period.

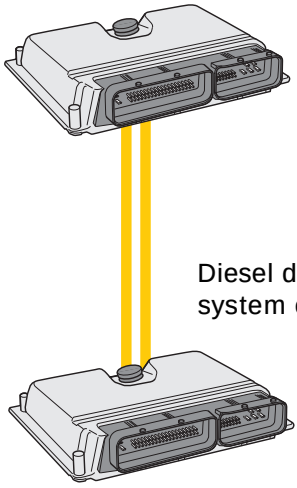
80 volts are required in order to activate the injectors for a short time. This calls for more highly rated output stages and capacitors. Therefore, the injectors of bank 2 can only by operated from the master control unit and the injectors of bank 1 can only be operated from the slave control unit.

The slave control unit controls the following electrical components:

- Fuel bypass valve N312
- Valve for fuel dosing N290
- Fuel pump relay J17 and fuel pump (pre-supply pump) G6
- Pump relay, fuel cooling J445 and pump for cooling fuel V166
- Alternator cut-in relay J442 (option)
- Fan (stage 1+2).

The control units intercommunicate by CAN-BUS.
The master control unit indicates to the slave control unit what functions it has to execute.

Diesel direct injection system control unit J248



Diesel direct injection system control unit 2 J494

SSP227_031

Self-diagnosis	Address word
master control unit	01
slave control unit	11

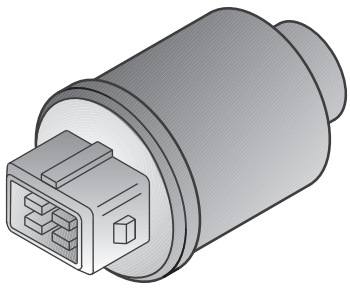
SSP186 describes how the CAN-BUS works.

Fuel temperature sender G81

The fuel temperature is acquired in the return line of the injectors. The temperature signal influences the following:

– The valve for fuel dosing N290 (the quantity of fuel to be compressed is regulated in order to reduce the temperature)
– The rail pressure
– The injection quantity for fuel temperatures over 118°C.

The sensor is of NTC type (negative temperature co-efficient).



SSP227_003

If the sender fails, no substitute signal is utilised.

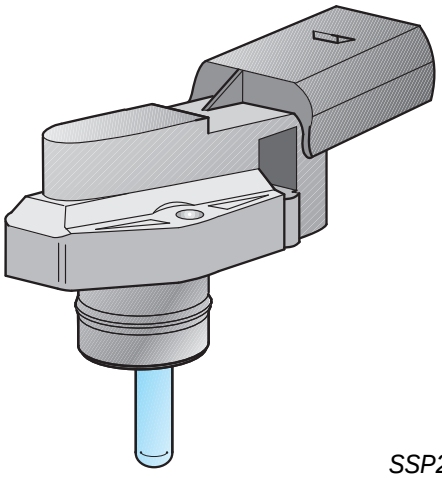
Intake manifold pressure sender G71

is a piezo-electric pressure sensor and is linked to the induction module by a hose pipe.

The signal is used for:

– charge pressure control

If the sensor fails, the charge pressure control is switched off.



SSP227_008

Result:
Loss of engine power

Fuel bypass valve N312

The valve is integrated in the bypass of the electric pre-supply pump.
It opens for 40 seconds when the ignition is turned "ON" (terminal 15) and closes during the starting cycle (terminal 50).

When the engine speed signal is input, the solenoid valve opens and allows fuel to be withdrawn directly from the baffle housing, bypassing the electric pre-supply pump.

Valve for fuel dosing N290

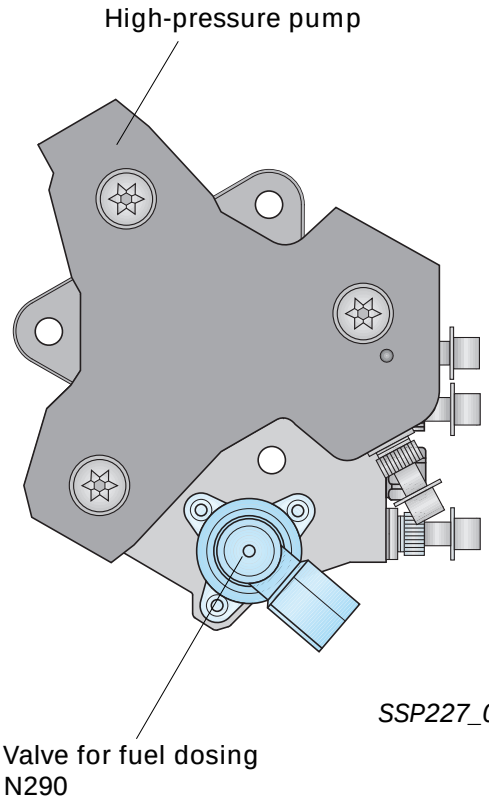
The valve for fuel dosing (intake restrictor) returns the fuel in accordance with power demand.

As a result, the quantity of fuel pumped and compressed is only slightly more than the quantity of fuel injected.

The power demand of the pump and fuel heating are reduced in this way.

If a malfunction occurs, the following happens:

– The exhaust gas recirculation is switched off
– The charge pressure control is switched off
– Full-throttle limitation



SSP227_020

To protect the engine when a fault in the system is registered, the engine is forcibly shut down via the intake restrictor.

Notes

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