

# **1.9-Liter TDI Engine with Pump Injection (Pumpe Düse) Design and Function**



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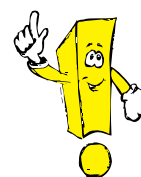
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**New!**



**Important/Note!**



The Self-Study Program provides you with information regarding designs and functions.

**The Self-Study Program is not a Repair Manual.**

For maintenance and repair work, always refer to the current technical literature.



## 1.9-Liter TDI Engine with Pump Injection System

The demands on the modern diesel engine for increased performance and fuel economy, and reduced exhaust emissions and noise levels are growing constantly.

Good fuel and air mixture preparation is a key factor in meeting these requirements.

This calls for efficient injection systems that produce high injection pressures to ensure that the fuel is well atomized. It is also necessary to precisely control the start of fuel injection and the injection quantity.

The pump injection system meets these requirements.

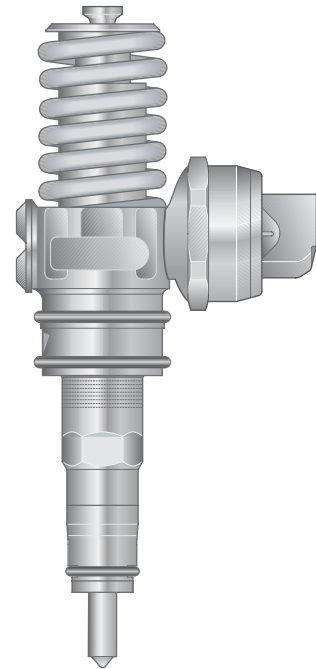
In 1905, Rudolf Diesel came up with the idea of a pump/injector, combining the injection pump and injector in one unit in order to dispense with high-pressure lines and achieve high injection pressures. At the time, however, he did not have the technical means to put his idea into practice.

Diesel engines with mechanically controlled pump injection systems have been in use in ships and trucks since the 1950s.

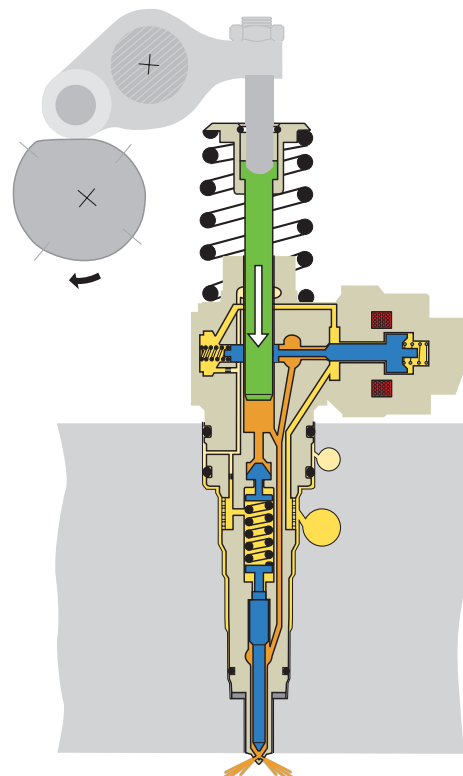
In association with Bosch, Volkswagen has succeeded in developing a diesel engine with a solenoid valve controlled pump injection system suitable for use in passenger cars.

The 1.9-liter TDI engine with the new pump injection system meets the stringent demands for improved performance and cleaner emissions.

With continuing advances like this one, Rudolf Diesel's vision of "smoke- and odor-free exhaust gases" may one day become a reality.



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## Development of the 1.9-Liter TDI Engine with Pump Injection System

The new 100 bhp (74 kW) 1.9-liter TDI engine with pump injection system was developed from the existing 109 bhp (81 kW) 1.9-liter TDI engine with a distributor injection pump and no intermediate shaft.

The pump injection system comprises the only significant difference between the two engines.

This Self-Study Program concerns the design and function of the new pump injection system, and the modifications to the fuel system, engine management system, and engine mechanical components to accommodate the system.

A diesel engine with the pump injection system has the following advantages over an engine with a distributor injection pump:

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

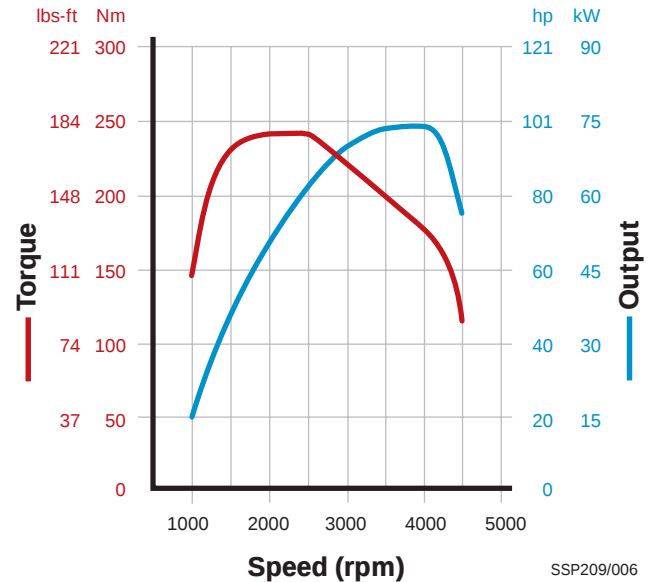
These advantages are attributable to:

- The high injection pressures of up to 27,846 psi (192,000 kPa / 1,920 bar).
- Precise control of the injection cycle.
- The pre-injection phase.

# Engine – Mechanics

## Technical Data – 1.9-Liter TDI Engine with Pump Injection System

- **Engine code**  
BEW
- **Type**  
Four-cylinder in-line engine with two valves per cylinder
- **Displacement**  
115.7 cu in (1,896 cm<sup>3</sup>)
- **Bore**  
3.13 in (79.5 mm)
- **Stroke**  
3.76 in (95.5 mm)
- **Compression ratio**  
19.0 : 1
- **Maximum power output**  
100 bhp (74 kW) @ 4000 rpm
- **Maximum torque**  
177 lbs-ft (240 Nm) @ 1800 to 2400 rpm
- **Engine management**  
EDC 16
- **Firing sequence**  
1-3-4-2
- **Emission Control**  
Bin 10 EPA Federal Emissions Concept, OBD II, catalytic converter, water-cooled EGR system

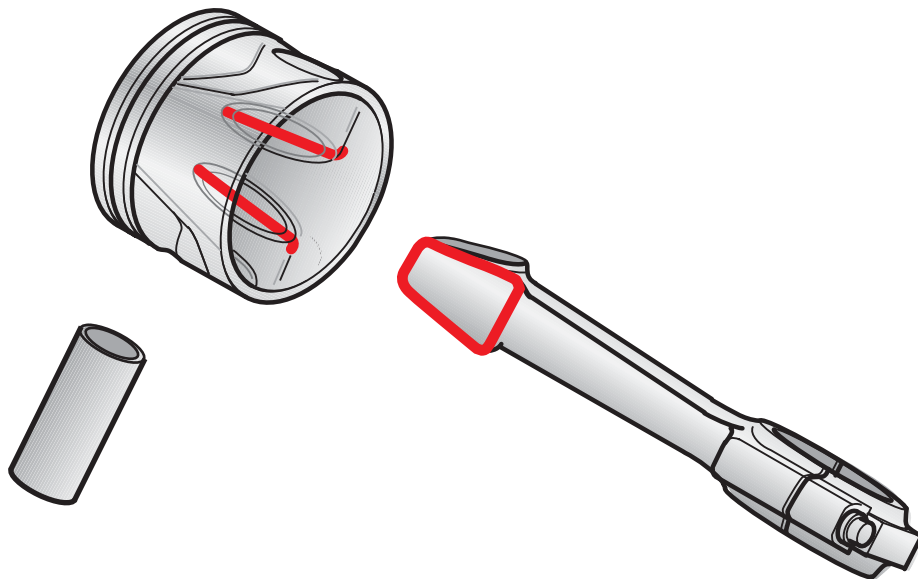


# Engine – Mechanics

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## Trapezoidal Piston and Connecting Rod

To accommodate the higher combustion pressures in the 1.9-liter TDI engine with pump injection system than are encountered in the base engine, the piston hub and the connecting rod eye are trapezoidal in shape.



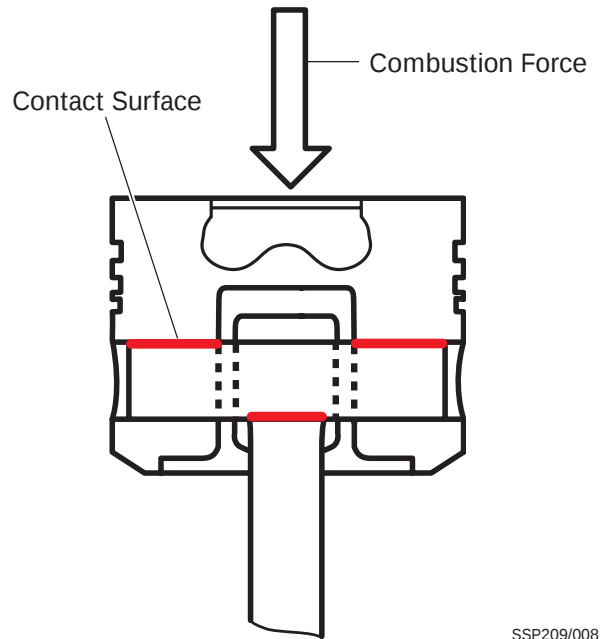
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# Engine – Mechanics

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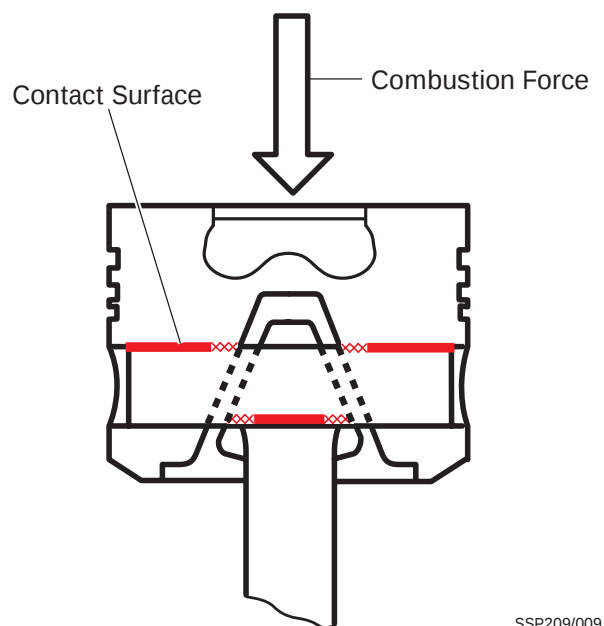
In comparison with the conventional parallelogram-shaped link between the piston and connecting rod, the trapezoidal connecting rod eye and piston hub have a larger contact surface area at the piston pin owing to their shape.

**Force Distribution in a Parallelogram-Shaped Piston and Connecting Rod**



This distributes the combustion forces over a larger area and relieves the load on the piston pin and connecting rod.

**Force Distribution in a Trapezoidal Piston and Connecting Rod**



# Engine – Mechanics

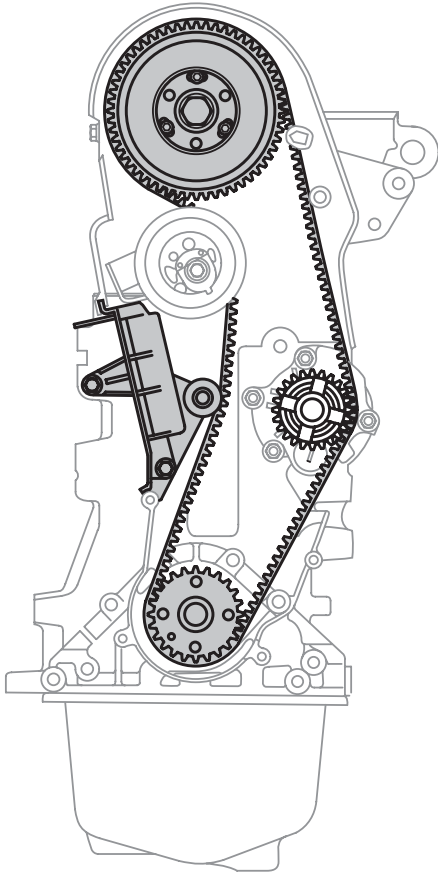
## Toothed Belt Drive

High pump forces are required to generate high injection pressures of up to 27,846 psi (192,000 kPa / 1,920 bar).

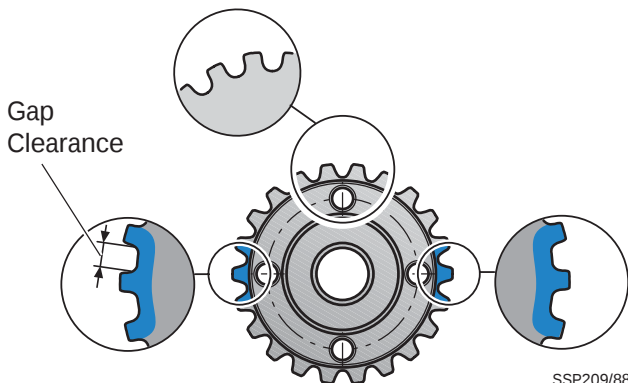
These forces subject the components of the toothed belt drive to high loads.

To relieve the load on the toothed belt, several modifications have been made.

- A vibration absorber integrated in the camshaft gear reduces vibration in the toothed belt drive.
- The toothed belt is about 0.20 inch (5 mm) wider than the toothed belt used in the base engine. Higher forces can be transmitted by the larger surface area.
- A hydraulic tensioner keeps the toothed belt evenly tensioned in different load states.
- Some of the teeth on the crankshaft timing belt gear have a larger gap clearance to reduce toothed belt wear.



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

## Function

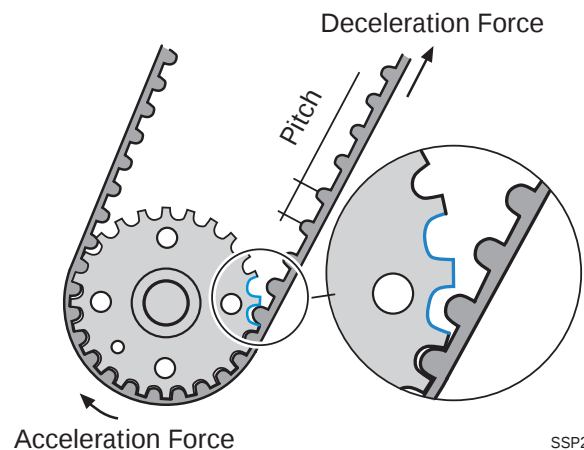
During the injection cycle, the high pumping forces exert a heavy load on the toothed belt.

The camshaft timing belt gear is slowed down by the pumping forces. At the same time, the combustion process speeds up the crankshaft timing belt gear. The toothed belt is stretched and the pitch is temporarily increased as a result.

Because of the engine firing order, this stretching process occurs at regular intervals and the same teeth on the timing belt gear are in mesh with the toothed belt every time.

## Non-uniform tooth gap clearance

On the 1.9-liter TDI engine with pump injection system, the crankshaft timing belt gear teeth have a larger gap clearance at these points to compensate for the change in belt tooth pitch and thus reduce toothed belt wear.



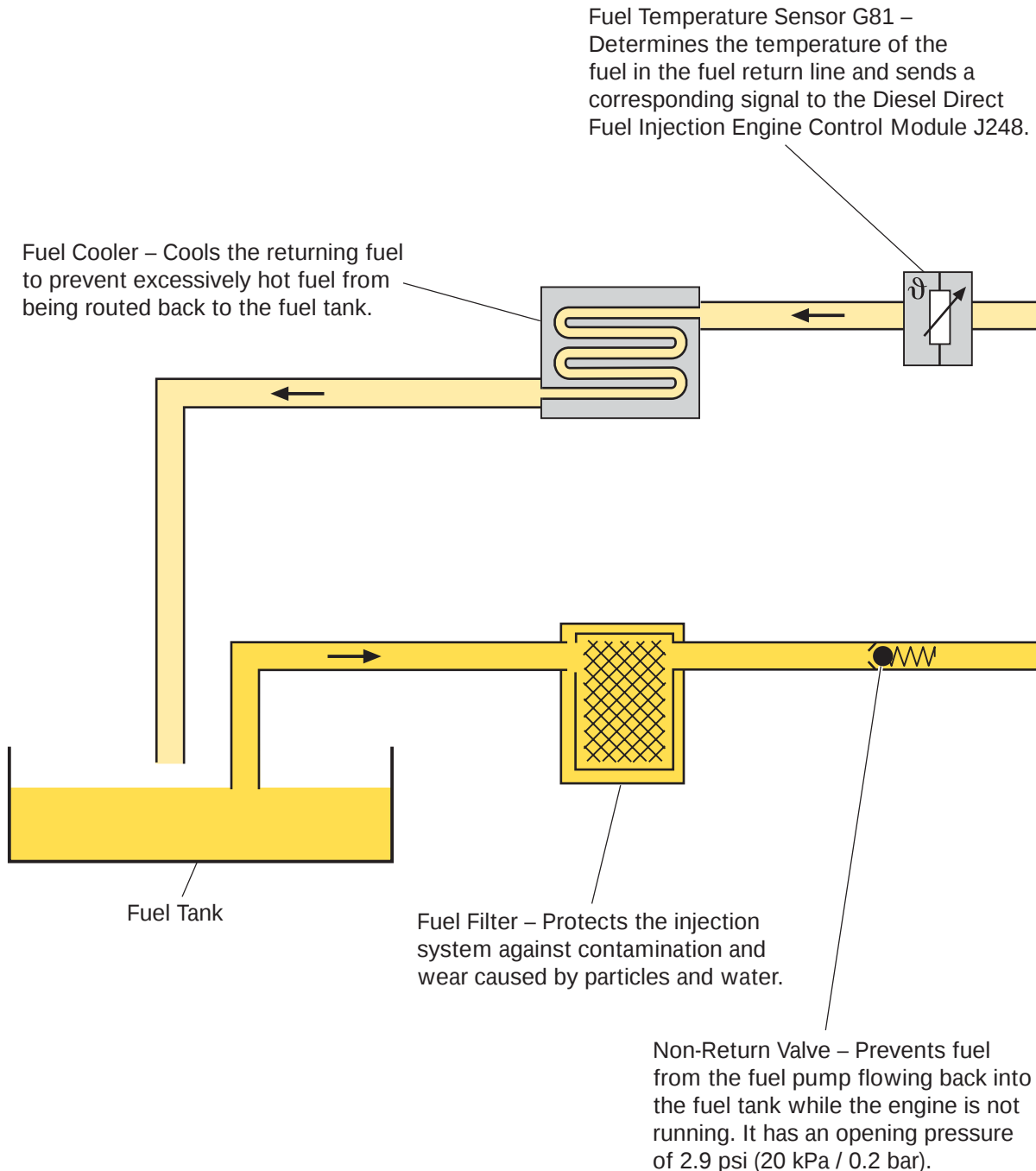
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# Fuel Supply

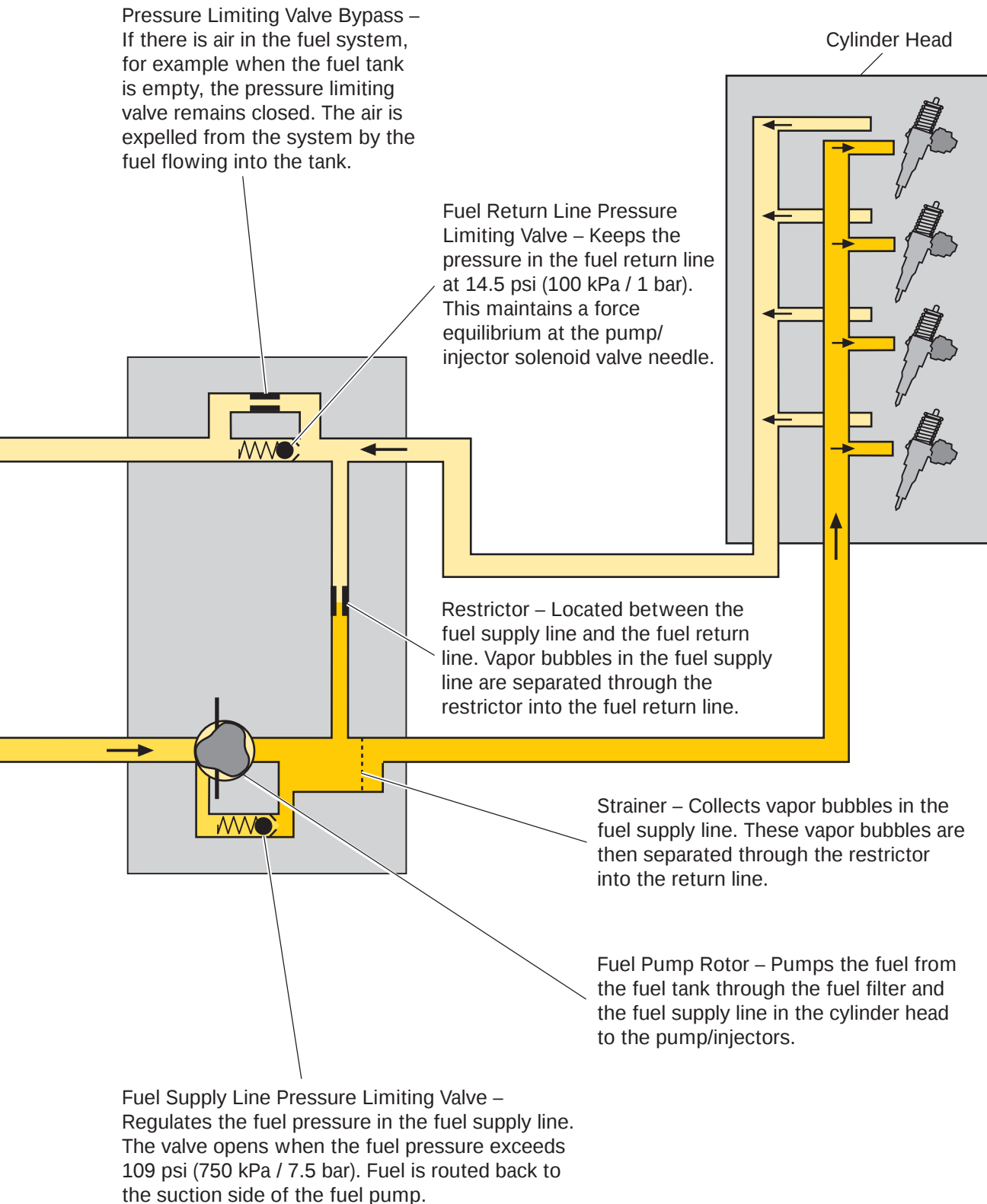
## Fuel Supply System Overview

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

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



# Fuel Supply



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# Fuel Supply

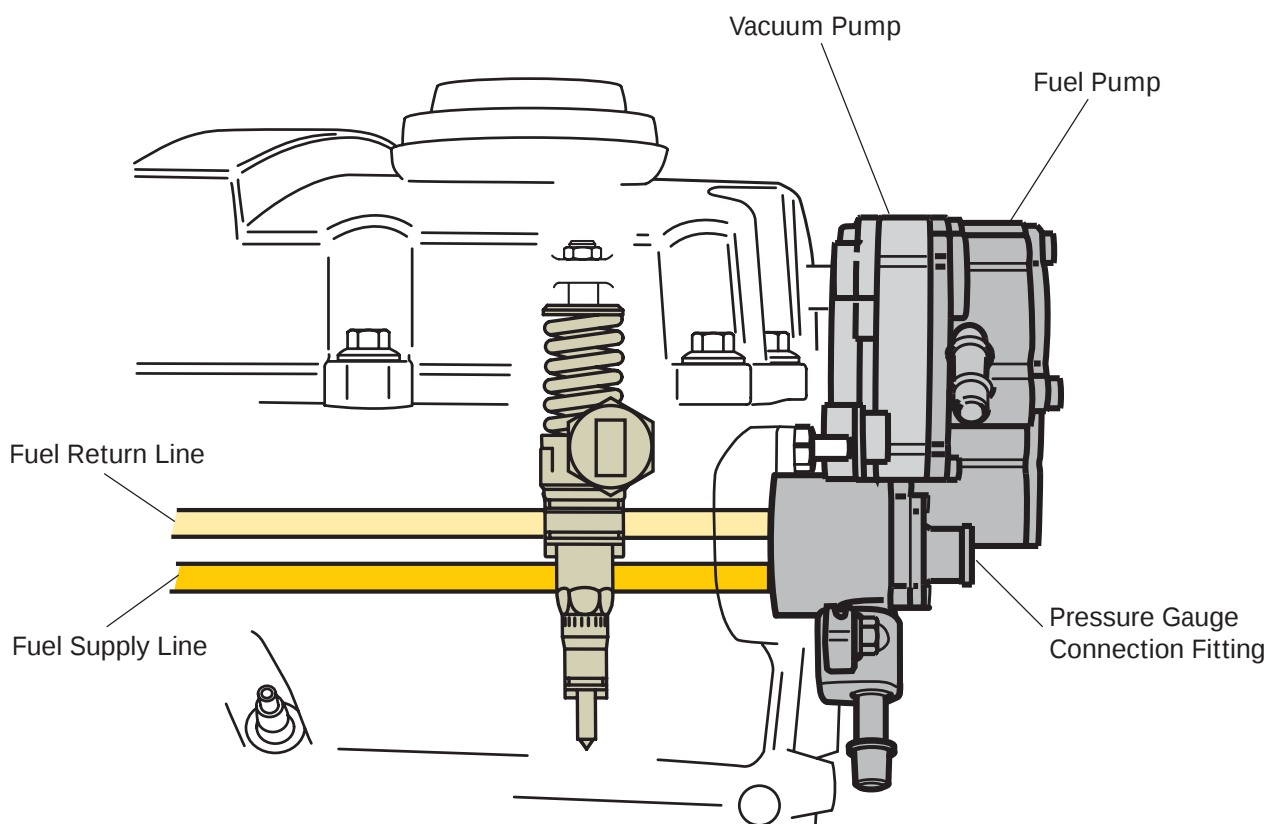
## Fuel Pump

The fuel pump is located directly behind the vacuum pump at the cylinder head. It moves the fuel from the fuel tank to the pump/injectors.

Both pumps are driven jointly by the camshaft. They are collectively known as a tandem pump.



There is a fitting on the fuel pump for connecting pressure gauge VAS 5187 to check the fuel pressure in the supply line. Please refer to the Repair Manual for instructions.

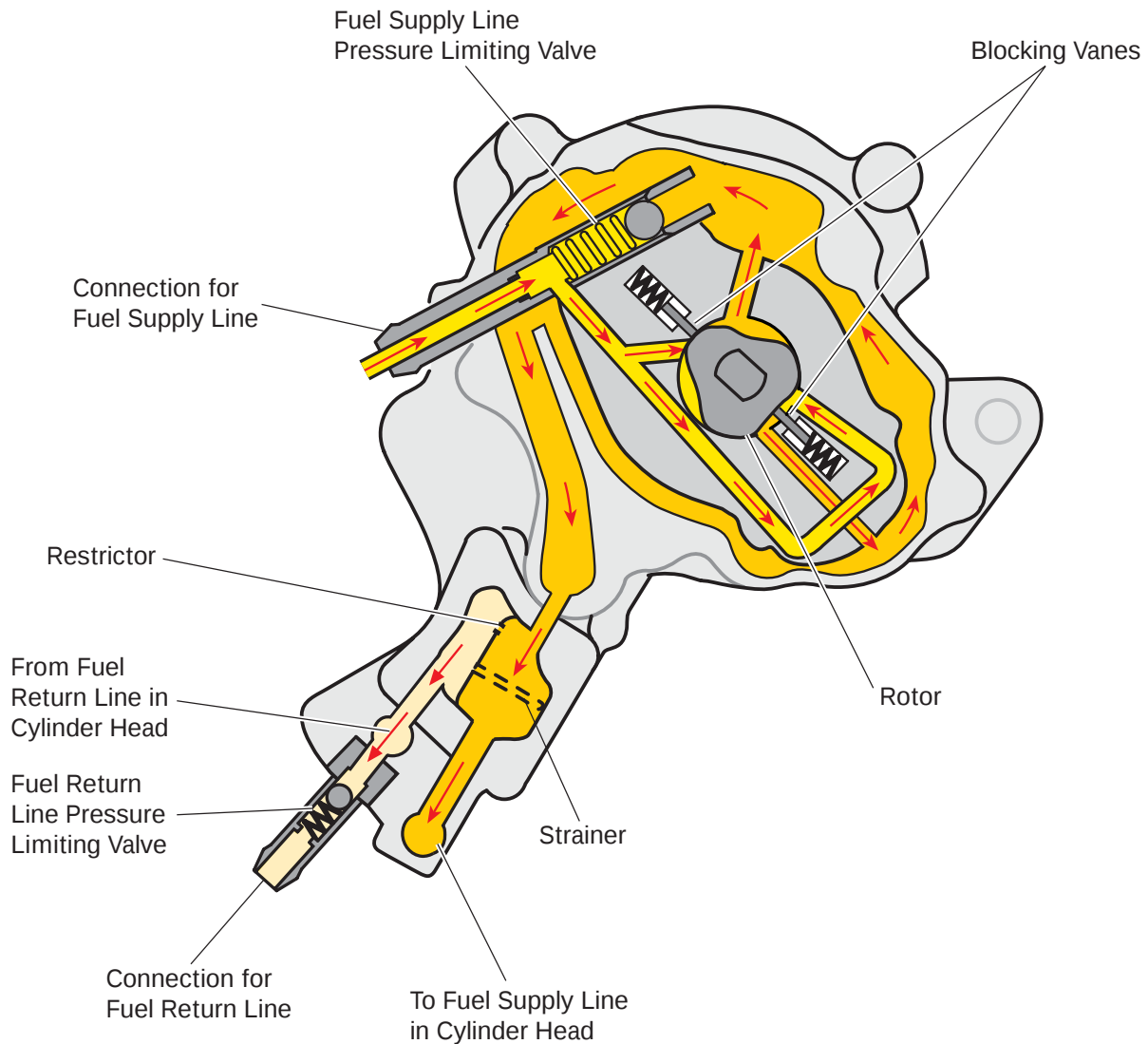


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# Fuel Supply

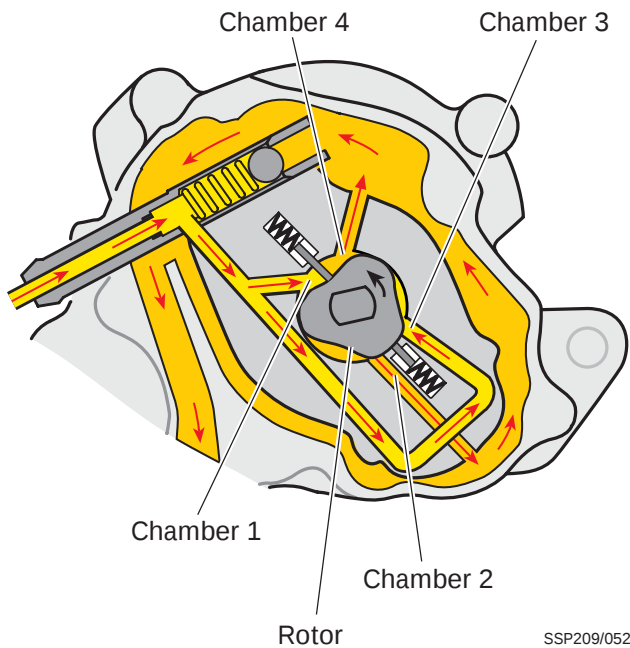
The fuel pump is a blocking vane-cell pump. The blocking vanes are pressed against the pump rotor by spring pressure. This design enables the fuel pump to deliver fuel even at low engine speeds.

The fuel ducting system within the pump is designed so that the rotor always remains wetted with fuel, even if the tank has been run dry. This makes automatic priming possible.



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# Fuel Supply



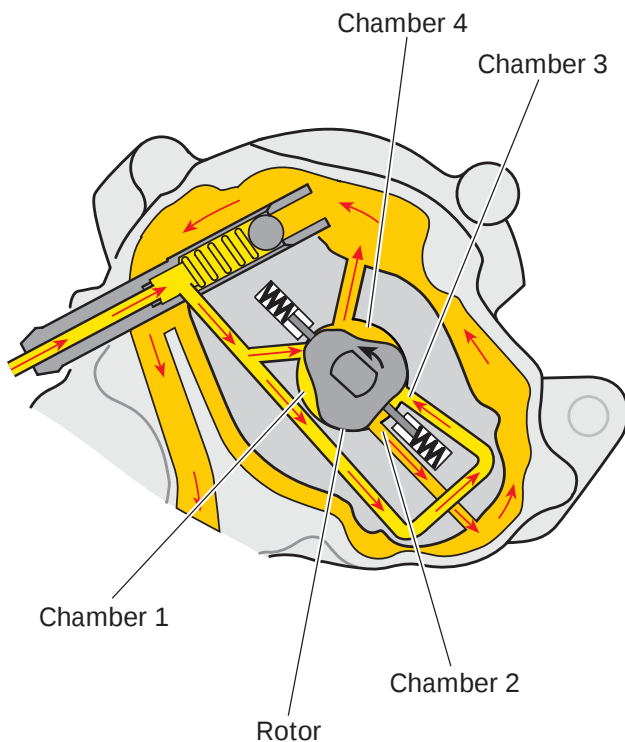
## Function

The fuel pump operates by taking fuel in as the pump chamber volume increases and pushing the fuel out under pressure as the chamber volume is reduced.

The fuel is drawn into two chambers and pumped out from two chambers. The intake and delivery chambers are separated from one another by the spring-loaded blocking vanes and the pump rotor lobes.

Fuel drawn into chamber 1 is pushed out at chamber 2. Fuel drawn into chamber 3 is pushed out at chamber 4.

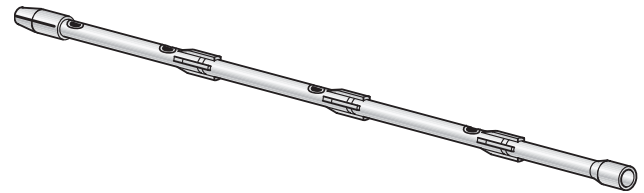
The rotation of the rotor increases the volume of chamber 1 while the volume of chamber 4 is simultaneously reduced. Fuel is pushed out of chamber 4 to the fuel supply line in the cylinder head.



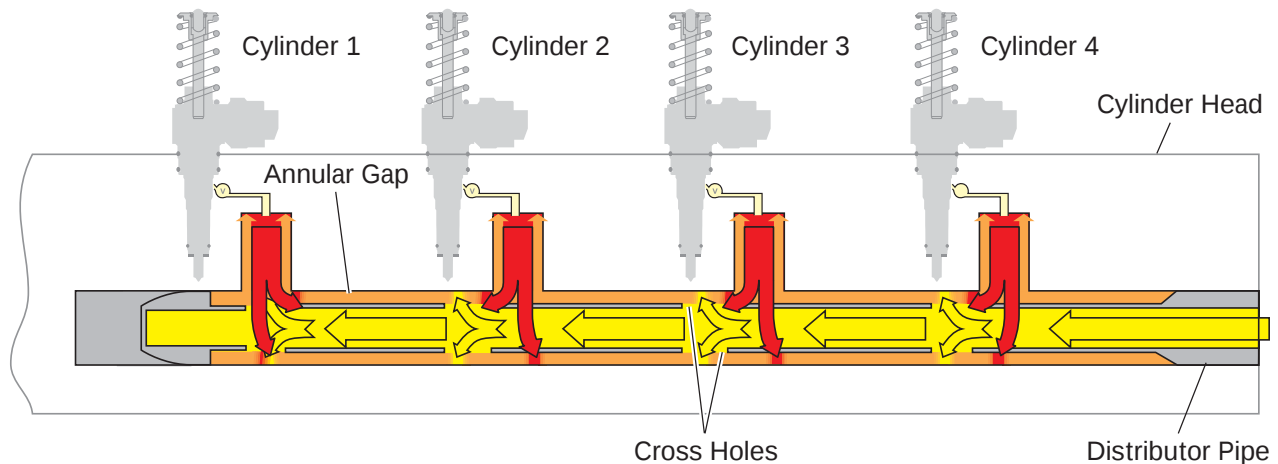
The rotation of the rotor increases the volume in chamber 3 as it reduces the volume in chamber 2. Fuel drawn in at chamber 1 is forced out of chamber 2 to the fuel supply line in the cylinder head.

## Distributor Pipe

A distributor pipe is integrated in the fuel supply line in the cylinder head. It distributes the fuel evenly to the pump/injectors at a uniform temperature.



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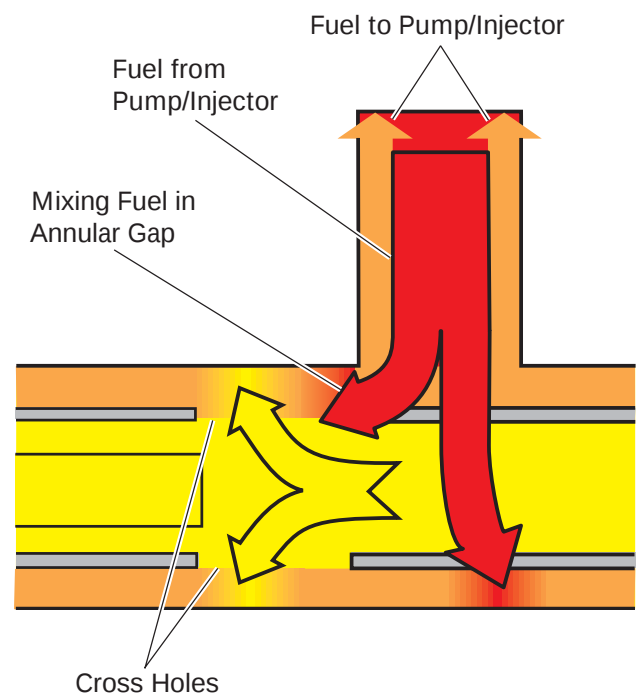
In the supply line, the fuel moves through the center of the distributor pipe toward cylinder 1 at the far end.

The fuel also moves through the cross holes in the distributor pipe and enters the annular gap between the distributor pipe and the cylinder head wall.

This fuel mixes with the hot unused fuel that has been forced back into the supply line by the pump/injectors.

This results in a uniform temperature of the fuel in the supply line running to all cylinders.

All pump/injectors are supplied with the same fuel mass, and the engine runs smoothly.



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# Fuel Supply

## Fuel Cooling System

The high pressure generated by the pump/injectors heats up the unused fuel so much that it must be cooled before it gets back to the fuel tank.

A fuel cooler is located on the fuel filter.

It cools the returning fuel and thus prevents excessively hot fuel from entering the fuel tank and possibly damaging the Sender for Fuel Gauge G.

## Fuel Cooling Circuit

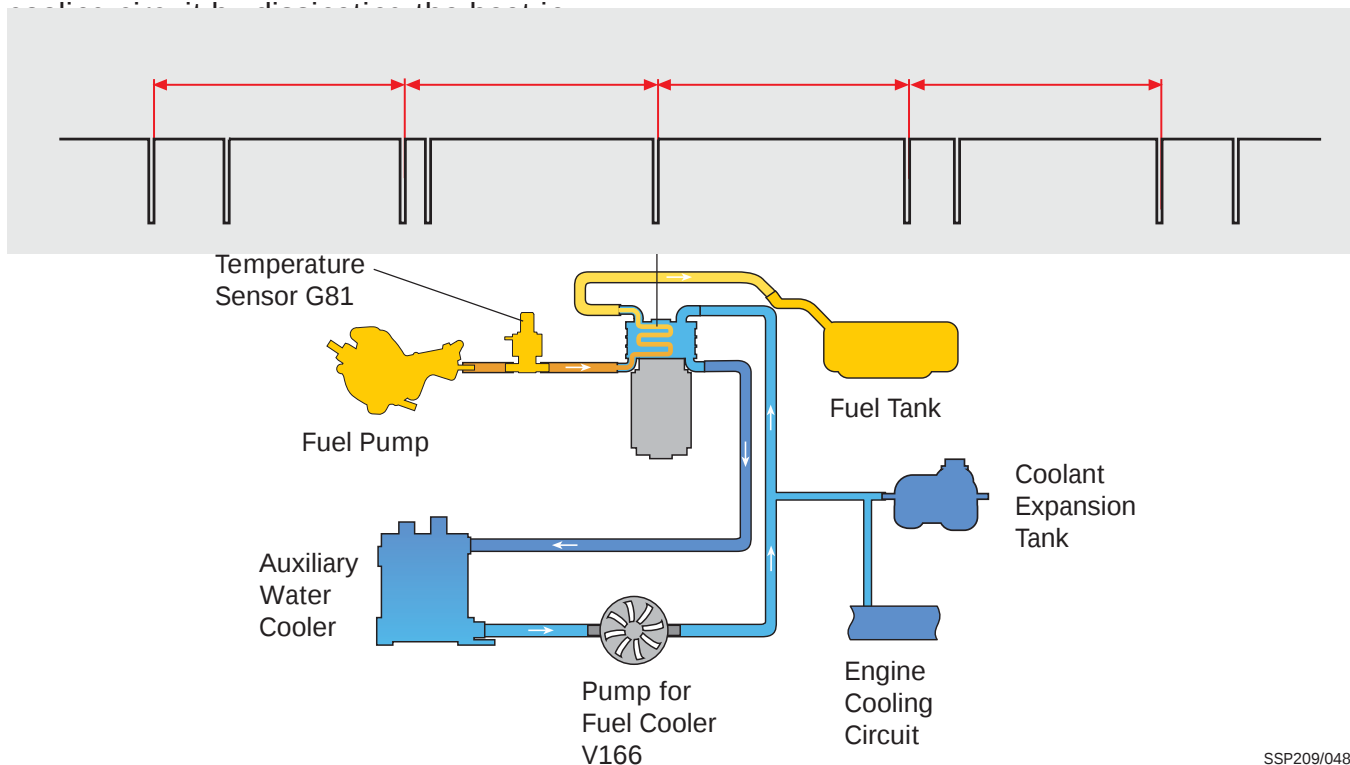
The heated fuel returning from the pump/injectors flows through the fuel cooler and its heat transfers to the coolant in the fuel cooling circuit that also flows through the fuel cooler.

The auxiliary water cooler reduces the temperature of the coolant in the fuel

Pump for Fuel Cooler V166 is an electric recirculation pump. It circulates the coolant in the fuel cooling circuit through the auxiliary water cooler and the fuel cooler. It is switched on by the Diesel Direct Fuel Injection Engine Control Module J248 via the Relay for Pump, Fuel Cooling J445 at a fuel temperature of 158°F (70°C).

The fuel cooling circuit is largely separate from the engine cooling circuit. This is necessary because the temperature of the coolant in the engine cooling circuit is too high to cool down the fuel when the engine is at operating temperature.

The fuel cooling circuit is connected to the engine cooling circuit near the expansion tank. This enables replenishment of the coolant for fuel cooling at the coolant expansion tank. It also allows compensation for changes in volume due to temperature fluctuation.



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# Pump Injection System

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## Pump/Injectors

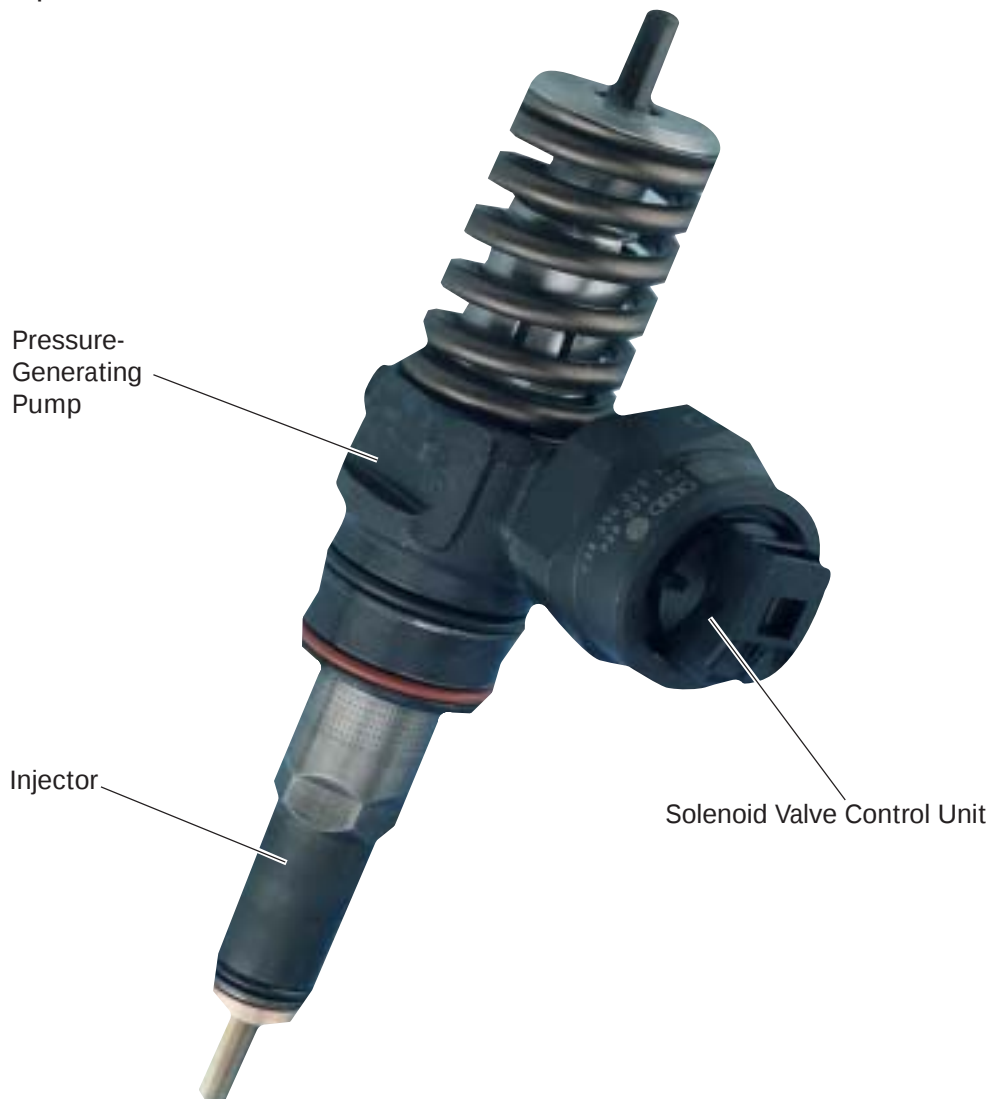
A pump/injector is, as the name implies, a pressure-generating pump combined with a solenoid valve control unit (Valves for Pump/Injectors, Cylinders 1 through 4, N240, N241, N242, and N243) and an injector.

Each cylinder of the engine has its own pump/injector.

This means that there is no longer any need for a high-pressure line or a distributor injection pump.

Just like a conventional system with a distributor injection pump and separate injectors, the new pump injection system must:

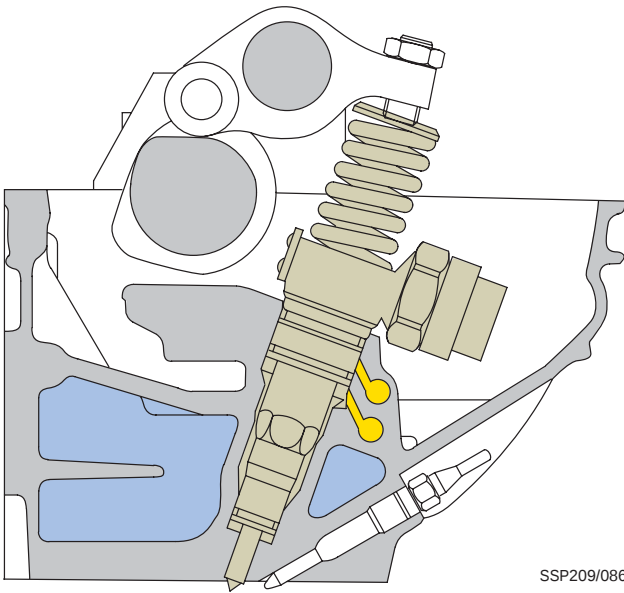
- Generate the high injection pressures required.
- Inject fuel into the cylinders in the correct quantity and at the correct point in time.



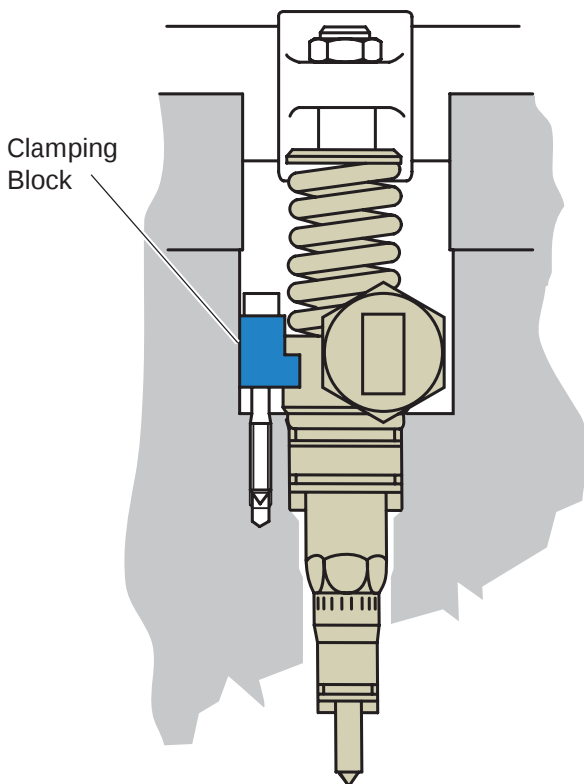
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# Pump Injection System

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The pump/injectors are installed directly in the cylinder head.



They are attached to the cylinder head by individual clamping blocks.

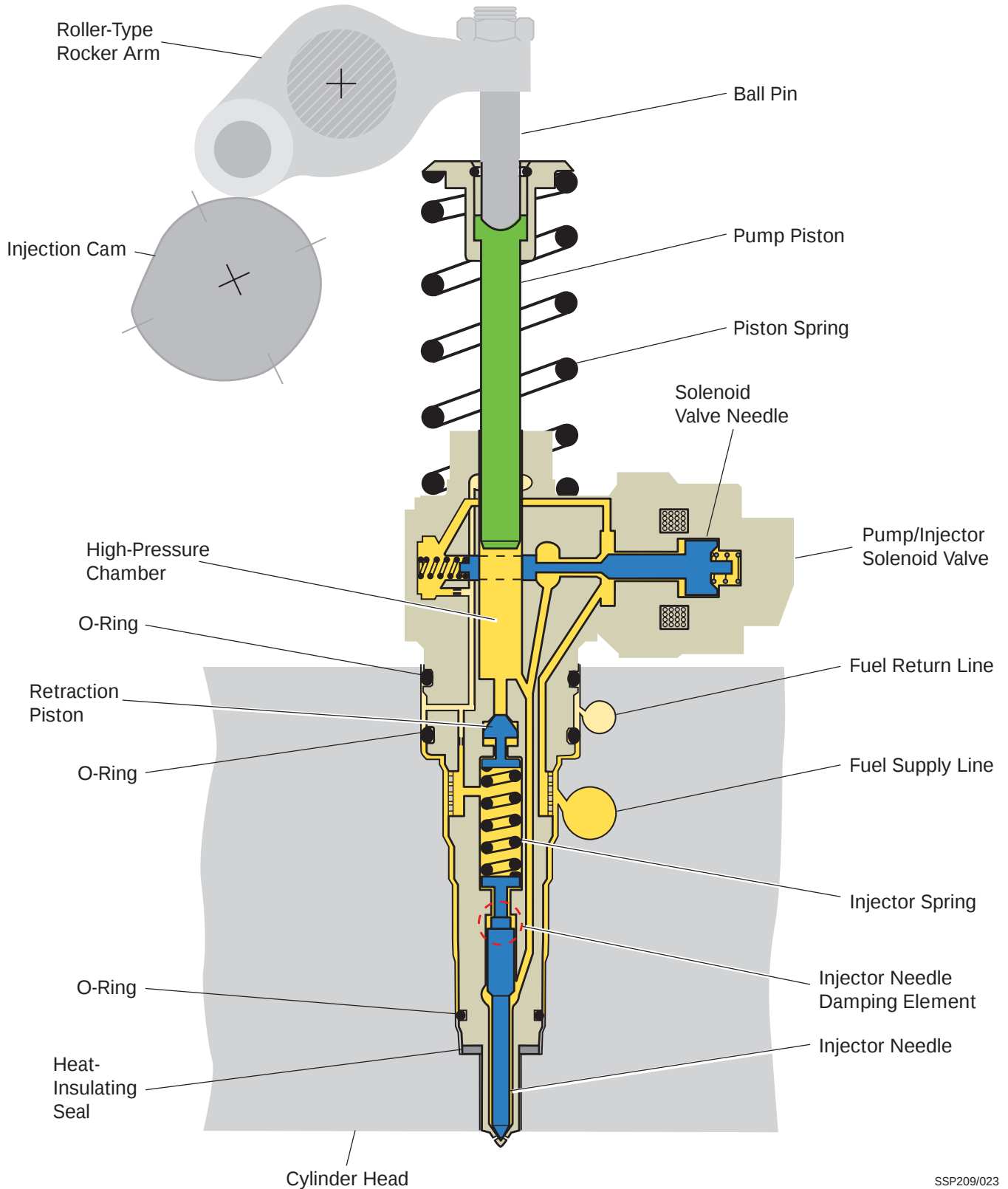


It is important to ensure that the pump/injectors are positioned correctly when they are installed. Refer to the Repair Manual for instructions.

If the pump/injectors are not installed perpendicular to the cylinder head, the fasteners could loosen. The pump/injectors or the cylinder head could be damaged as a result.

# Pump Injection System

## Design



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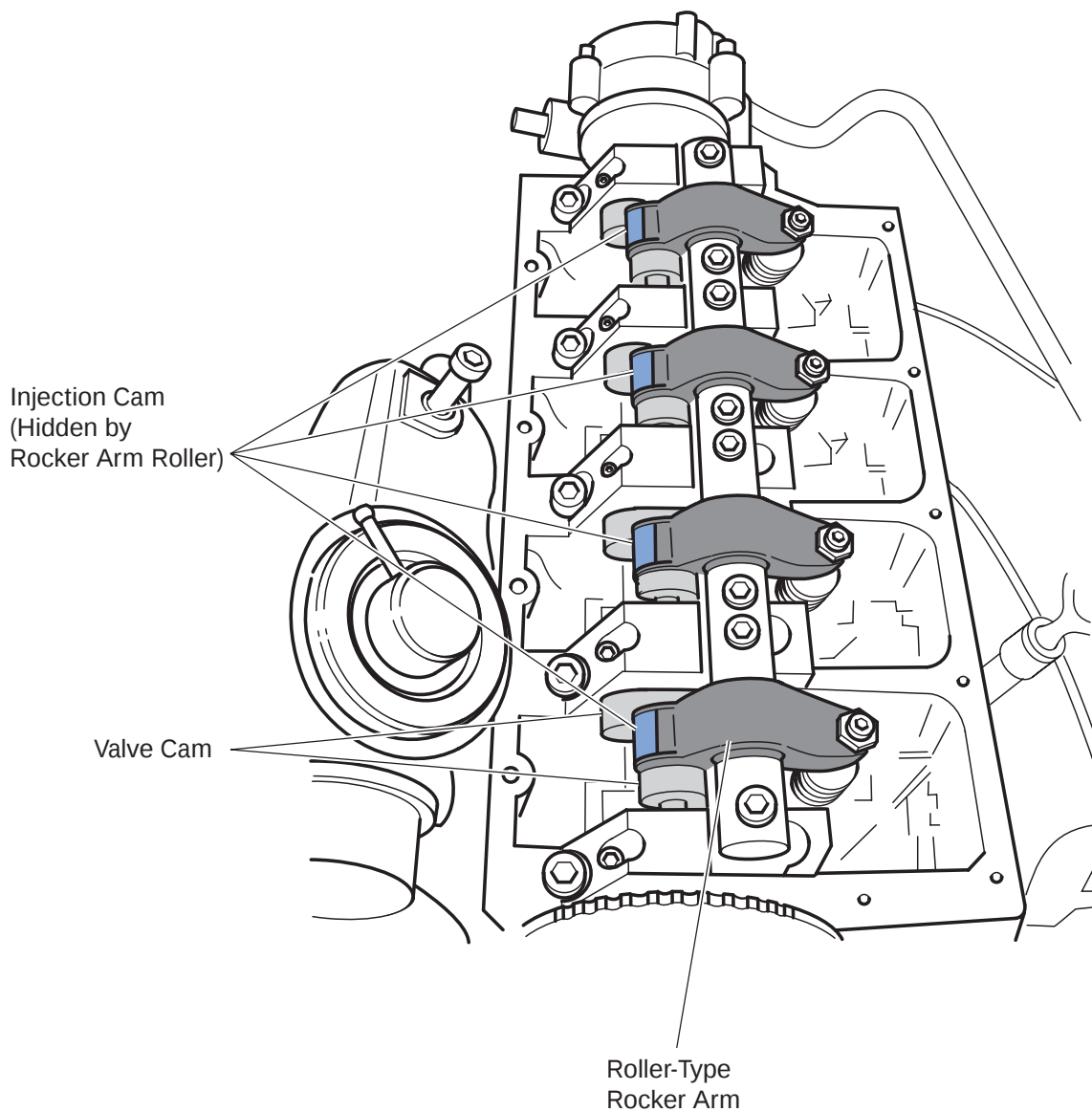
# Pump Injection System

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## Drive Mechanism

The camshaft has four additional cams for driving the pump/injectors.

They activate the pump/injector pump pistons with roller-type rocker arms.

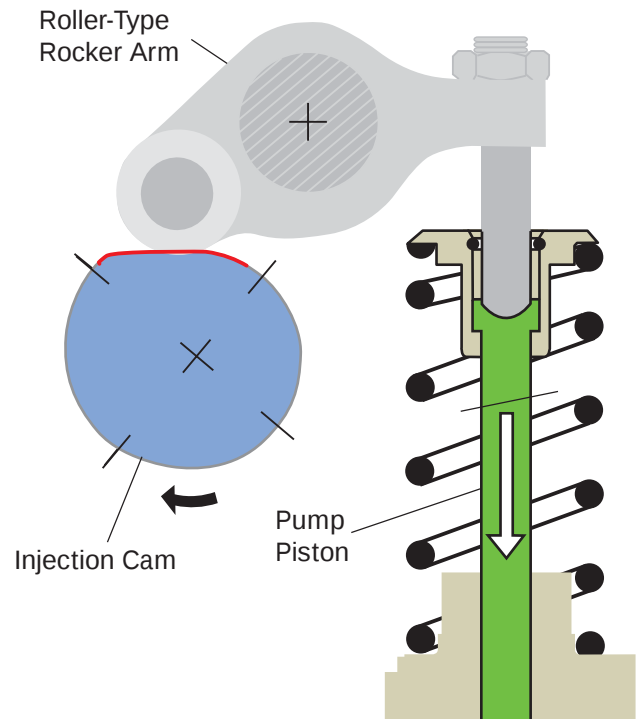


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# Pump Injection System

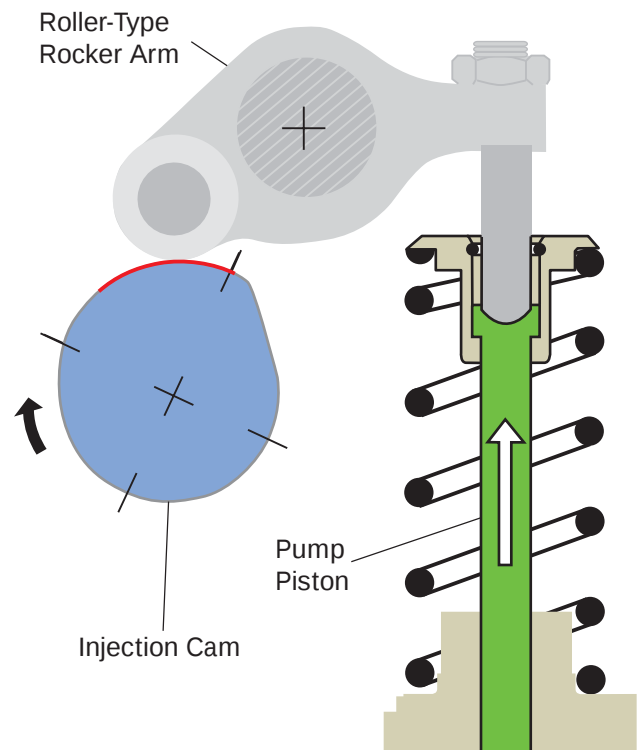
The injection cam has a steep leading edge and a gradual slope to the trailing edge.

As a result of the steep leading edge, the pump piston is pushed down at high velocity. A high injection pressure is attained quickly.



SSP209/016

The gradual slope of the cam trailing edge allows the pump piston to move up relatively slowly and evenly. Fuel flows into the pump/injector high-pressure chamber free of air bubbles.



SSP209/017

# Pump Injection System

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## Mixture Formation and Combustion Requirements

Good mixture formation is a vital factor to ensure efficient combustion.

Accordingly, fuel must be injected in the correct quantity at the right time and at high pressure. Even minimal deviations can lead to higher levels of pollutant emissions, noisy combustion, or high fuel consumption.

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

## Pre-injection phase

To soften the combustion process, a small amount of fuel is injected at a low pressure before the start of the main injection phase.

This is the pre-injection phase. Combustion of this small quantity of fuel causes the pressure and temperature in the combustion chamber to rise.

This meets the requirements for quick ignition of the main injection quantity, thus reducing the firing delay.

The pre-injection phase and the “injection interval” between the pre-injection phase and the main injection phase produce a gradual rise in pressure within the combustion chamber, not a sudden pressure buildup.

The effects of this are low combustion noise levels and lower nitrogen oxide emissions.

## Main injection phase

The key requirement for the main injection phase is the formation of a good mixture. The aim is to burn the fuel completely if possible.

The high injection pressure finely atomizes the fuel so that the fuel and air can mix well with one another.

Complete combustion reduces pollutant emissions and ensures high engine efficiency.

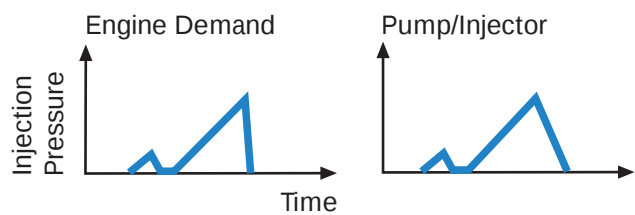
## End of injection

At the end of the injection process, it is important that the injection pressure drops quickly and the injector needle closes quickly.

This prevents fuel at a low injection pressure and with a large droplet diameter from entering the combustion chamber. Fuel does not combust completely under such conditions, giving rise to higher pollutant emissions.

## Injection curve

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



# Pump Injection System

## Injection Cycle

### High-Pressure Chamber Fills

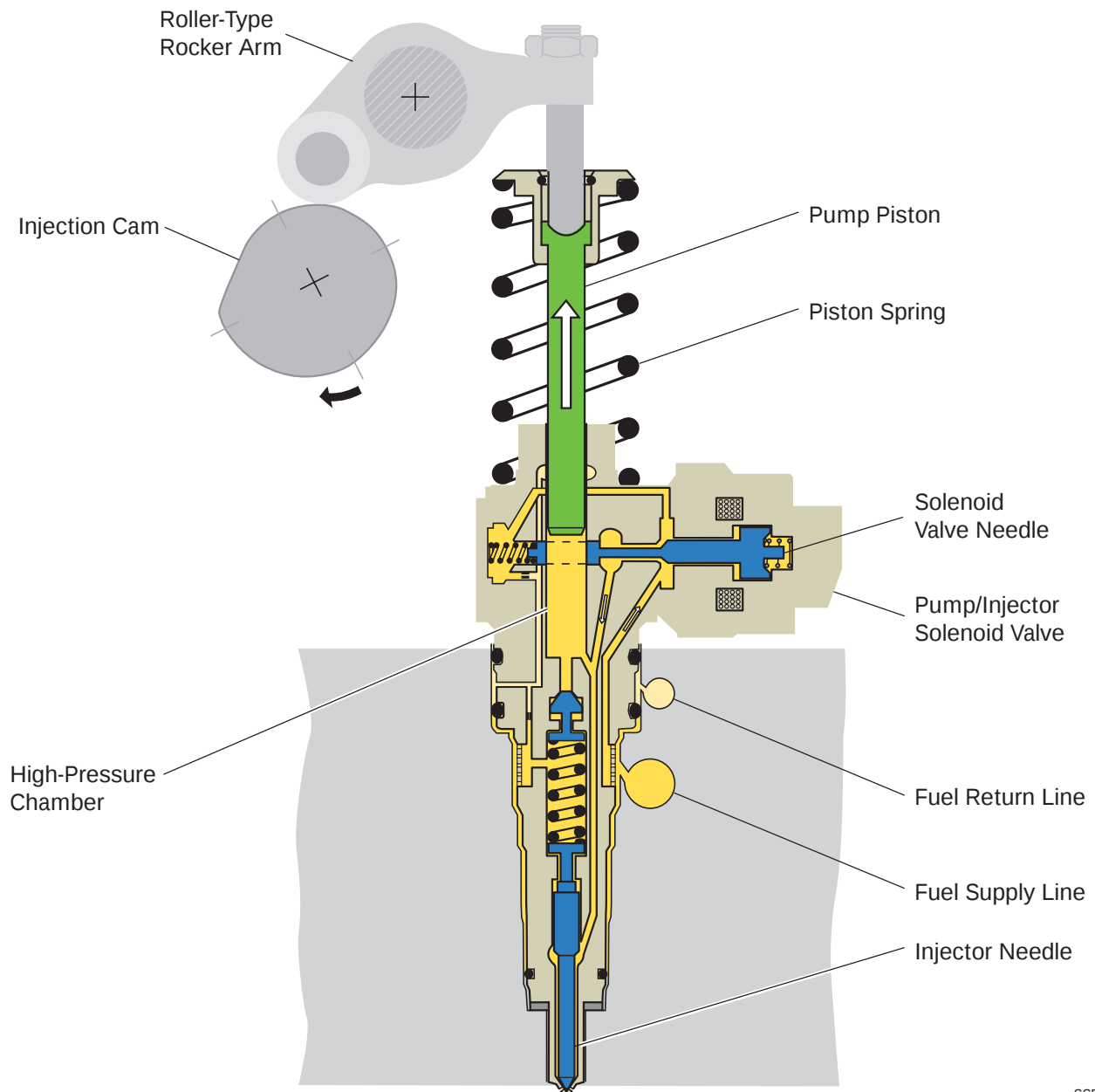
During the filling phase, the pump piston moves upward under the force of the piston spring and thus increases the volume of the high-pressure chamber.

The pump/injector solenoid valve is not activated.

The solenoid valve needle is in its resting position.

The path is open from the fuel supply line to the high-pressure chamber.

The fuel pressure in the supply line causes the fuel to flow into the high-pressure chamber.



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# Pump Injection System

## Pre-Injection Phase Starts

The injection cam pushes the pump piston down via the roller-type rocker arm. This displaces some of the fuel from the high-pressure chamber back into the fuel supply line.

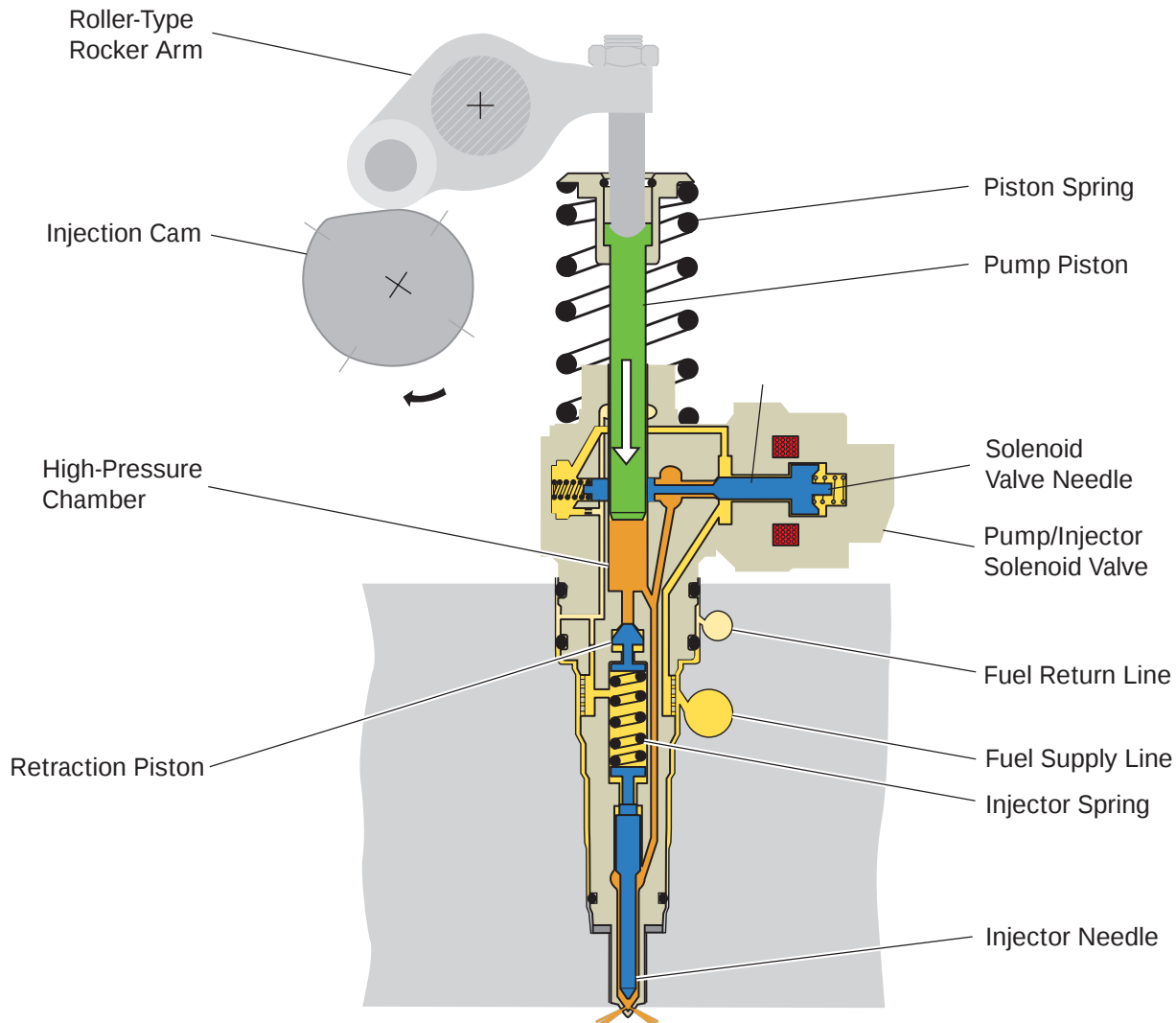
The Diesel Direct Fuel Injection Engine Control Module J248 initiates the injection cycle by activating the pump/injector solenoid valve.

The solenoid valve needle is pressed into the valve seat and closes the path from the high-pressure chamber to the fuel supply line.

This initiates a pressure build-up in the high-pressure chamber.

At 2,611 psi (18,000 kPa / 180 bar), the pressure is greater than the force of the injector spring.

The injector needle is lifted from its seat and the pre-injection cycle starts.



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# Pump Injection System

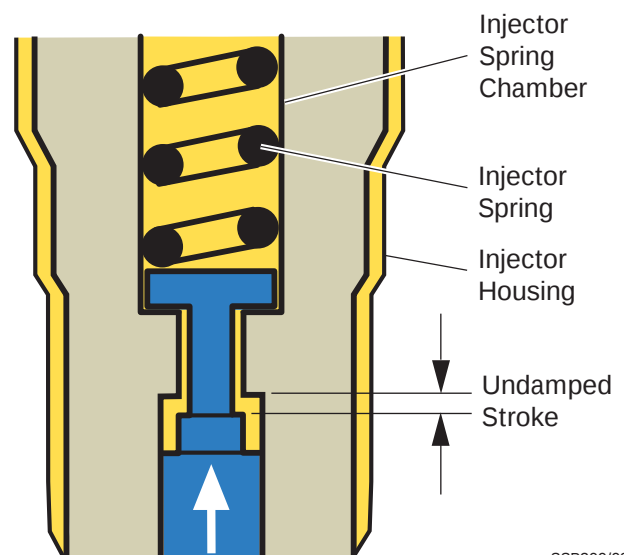
## Injector needle damping

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

### Function

In the first third of the total stroke, the injector needle is opened undamped.

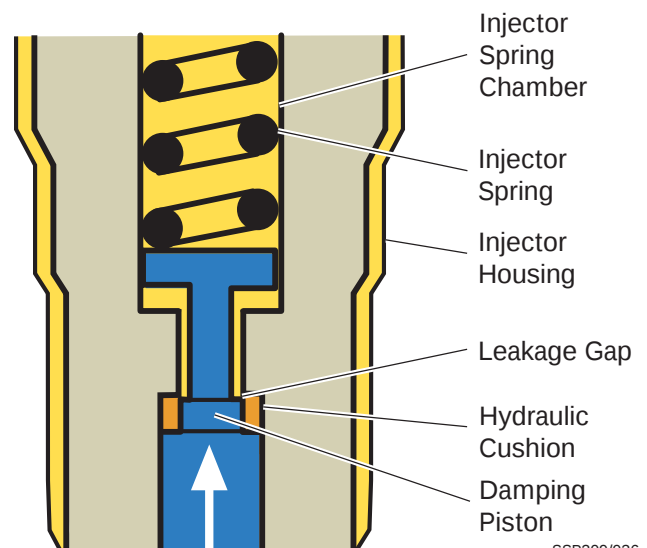
The pre-injection quantity is injected into the combustion chamber.



SSP209/035

As soon as the damping piston plunges into the bore in the injector housing, the fuel above the injector needle can only be displaced into the injector spring chamber through a leakage gap.

This creates a hydraulic cushion which limits the injector needle stroke during the pre-injection phase.



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# Pump Injection System

## Pre-Injection Phase Ends

The pre-injection phase ends immediately after the injector needle opens.

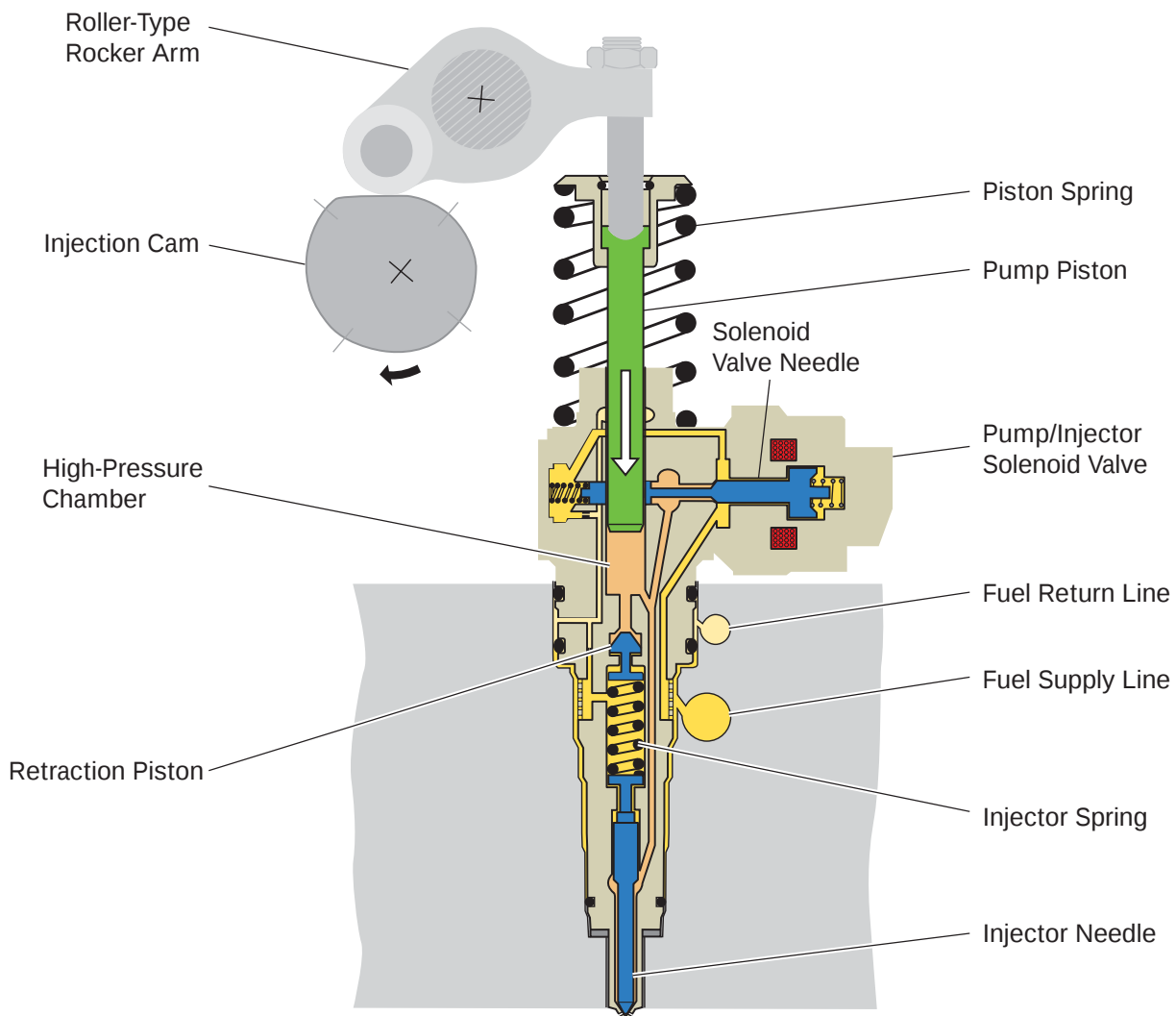
The rising pressure causes the retraction piston to move downward, thus increasing the volume of the high-pressure chamber.

The pressure drops momentarily as a result, and the injector needle closes.

This ends the pre-injection phase.

The downward movement of the retraction piston pre-loads the injector spring to a greater extent.

To re-open the injector needle during the subsequent main injection phase, the fuel pressure must be greater than during the pre-injection phase.



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# Pump Injection System

## Main Injection Phase Starts

The pressure in the high-pressure chamber rises again shortly after the injector needle closes.

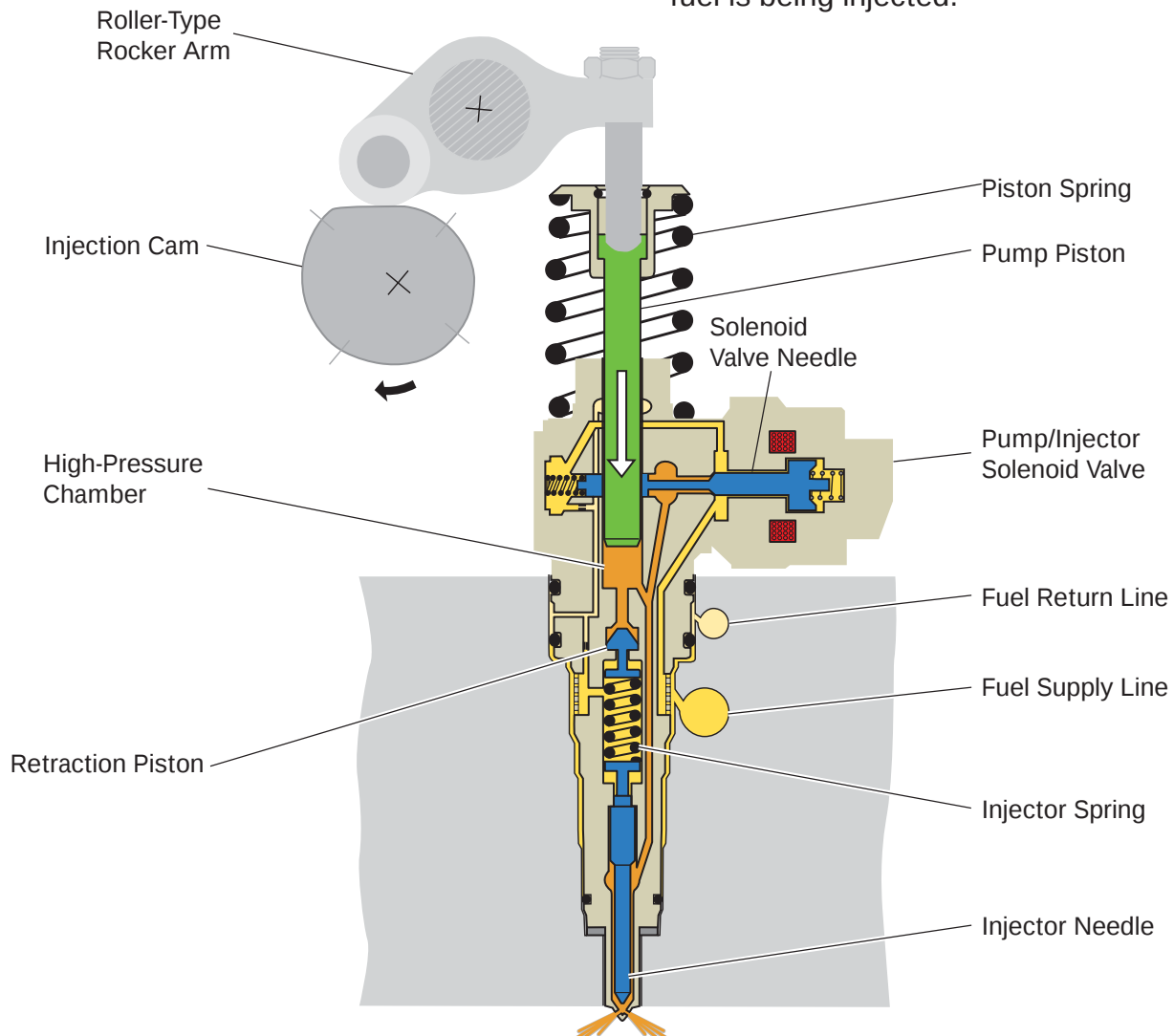
The pump/injector solenoid valve remains closed and the pump piston moves downward.

At approximately 4,351 psi (30,000 kPa / 300 bar), the fuel pressure is greater than the force exerted by the pre-loaded injector spring.

The injector needle is again lifted from its seat and the main injection quantity is injected.

The pressure rises to between 27,121 psi (187,000 kPa / 1,870 bar) and 27,846 psi (192,000 kPa / 1,920 bar) because more fuel is displaced in the high-pressure chamber than can escape through the nozzle holes.

Maximum fuel pressure is achieved at maximum engine output. This occurs at a high engine speed when a large quantity of fuel is being injected.



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# Pump Injection System

## Main Injection Phase Ends

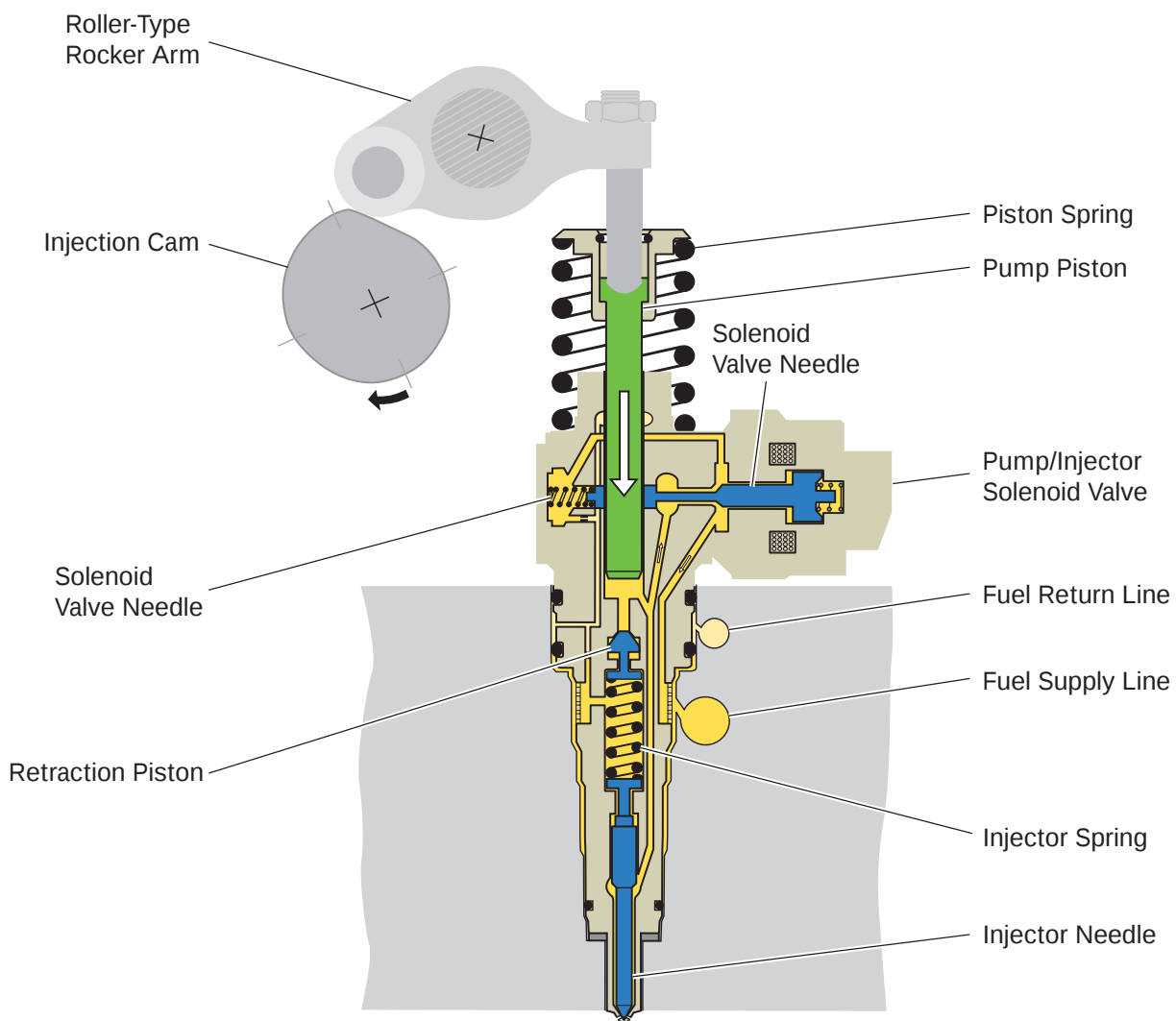
The injection cycle ends when the Diesel Direct Fuel Injection Engine Control Module J248 stops activating the pump/injector solenoid valve.

The solenoid valve spring opens the solenoid valve needle, and the fuel displaced by the pump piston can enter the fuel supply line.

The pressure drops.

The injector needle closes and the injector spring presses the bypass piston into its starting position.

This ends the main injection phase.



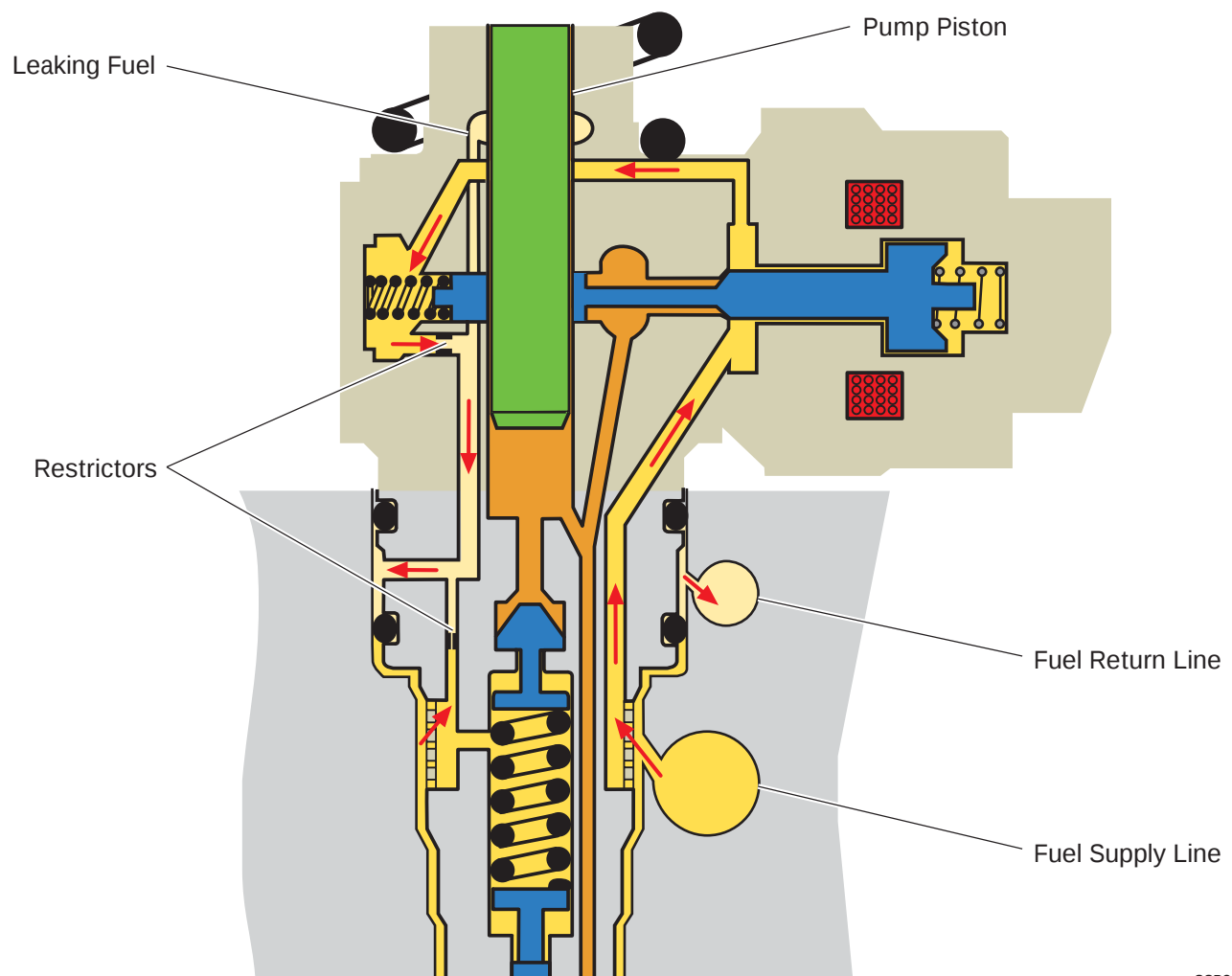
SSP209/028

# Pump Injection System

## Pump/Injector Fuel Return

The fuel return line in the pump/injector has the following functions:

- Cool the pump/injector by flushing fuel from the fuel supply line through the pump/injector ducts into the fuel return line.
- Discharge leaking fuel at the pump piston.
- Separate vapor bubbles from the pump/injector fuel supply line through the restrictors in the fuel return line.



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# Engine Management

## 1.9-Liter TDI Engine EDC 16 System Overview

### Sensors

Mass Air Flow Sensor G70

Engine Speed Sensor G28

Camshaft Position Sensor G40

Throttle Position Sensor G79

Kick Down Switch F8

Closed Throttle Position Switch F60

Engine Coolant Temperature Sensor G62

Manifold Absolute Pressure Sensor G71

Intake Air Temperature Sensor G72

Clutch Vacuum Vent Valve Switch F36

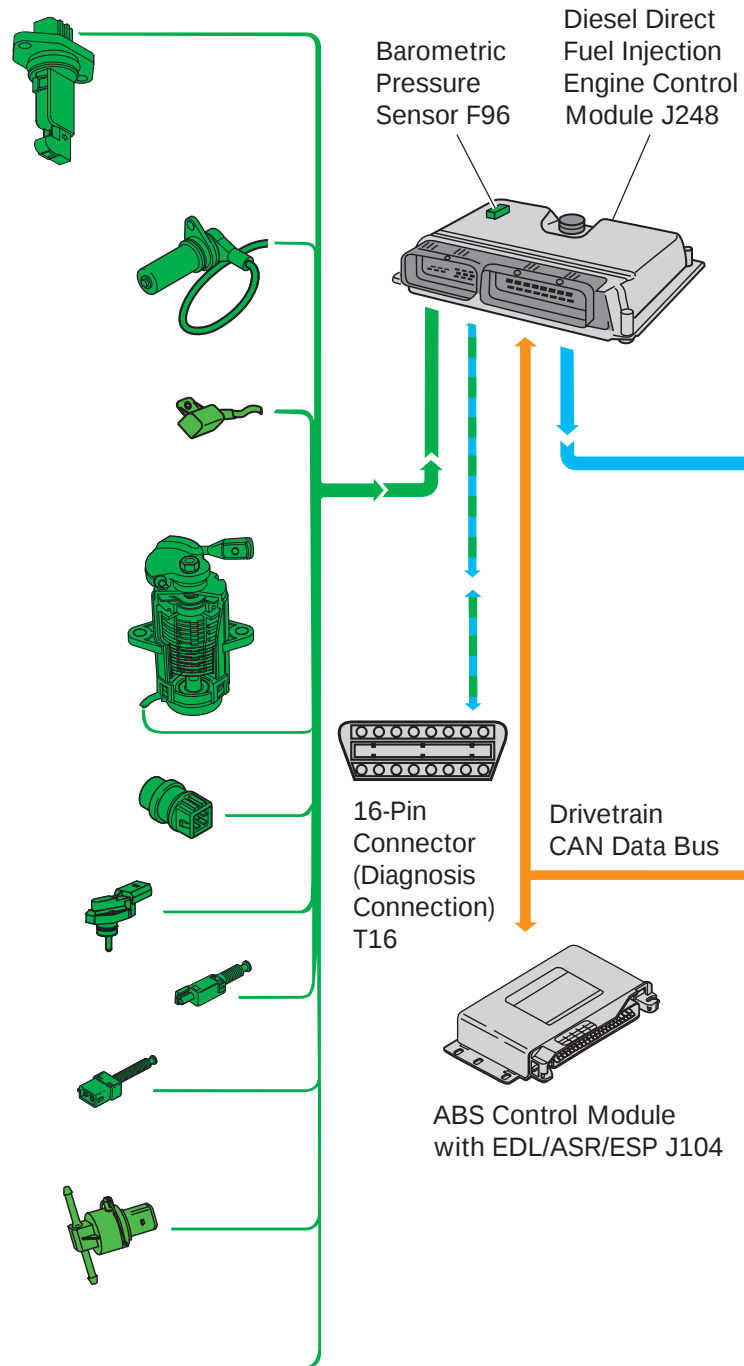
Brake Light Switch F

Brake Pedal Switch F47

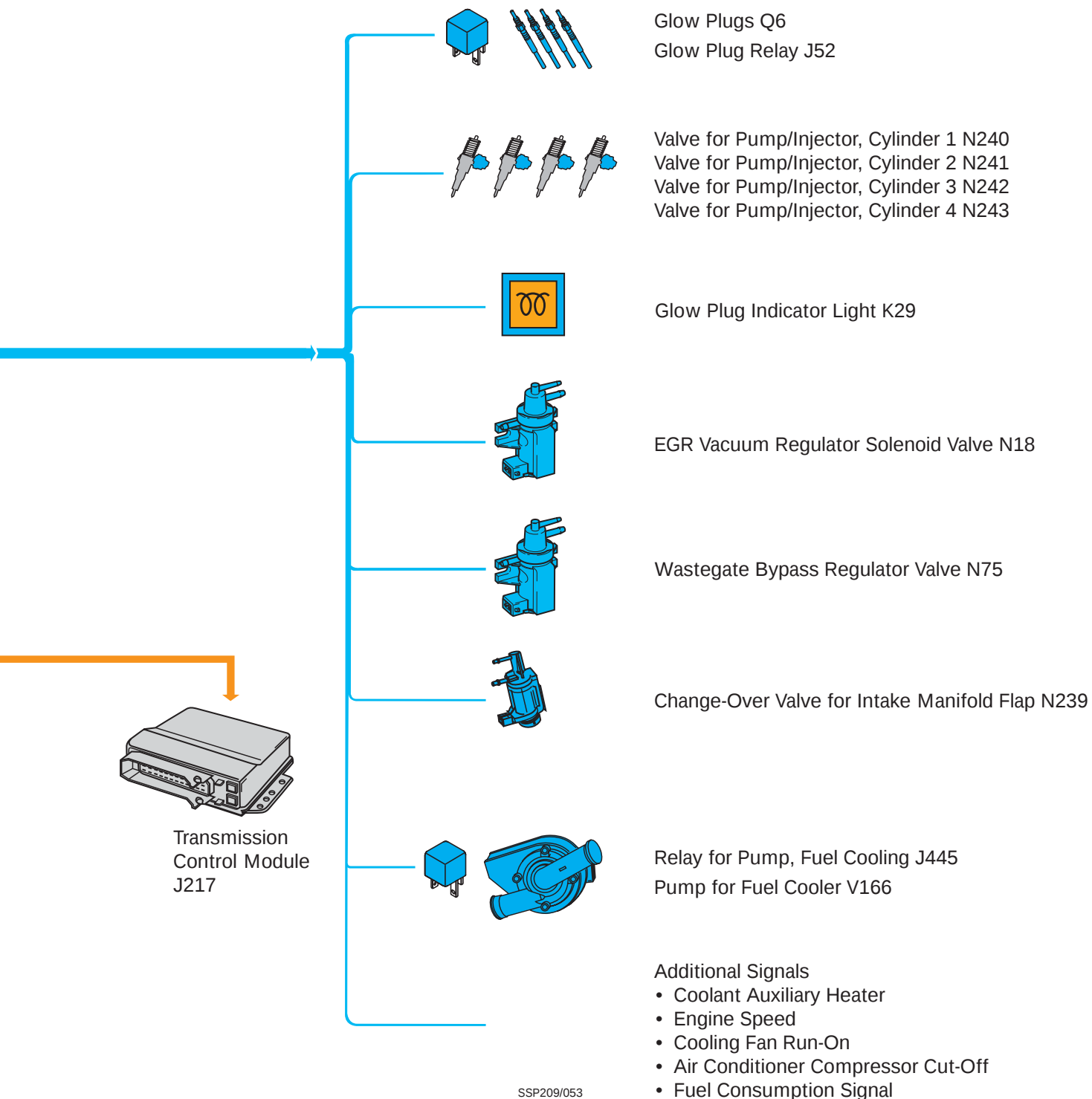
Fuel Temperature Sensor G81

Additional Signals

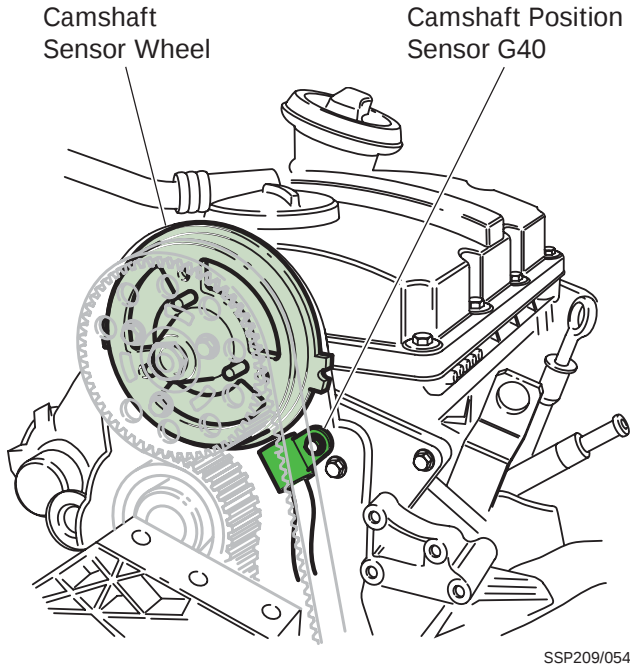
- Road Speed Signal
- Air Conditioner Compressor Ready
- CCS Switch
- Three-Phase AC Generator Terminal DF



## Actuators



# Engine Management



## Sensors

### Camshaft Position Sensor G40

The Camshaft Position Sensor G40 is a Hall-effect sensor.

It is attached to the toothed-belt guard below the camshaft gear.

It scans seven teeth on the camshaft sensor wheel attached to the camshaft gear.

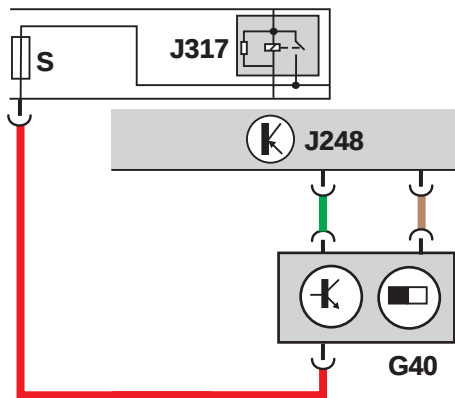
### Signal application

The Diesel Direct Fuel Injection Engine Control Module J248 uses the signal that the Camshaft Position Sensor G40 generates to determine the relative positions of the pistons in the cylinders when starting the engine.

### Effects of signal failure

In the event of Camshaft Position Sensor G40 signal failure, the Diesel Direct Fuel Injection Engine Control Module J248 uses the signal that the Engine Speed Sensor G28 generates.

### Electrical circuit



G40 Camshaft Position Sensor

J248 Diesel Direct Fuel Injection Engine Control Module

J317 Power Supply (Terminal 30, B+) Relay

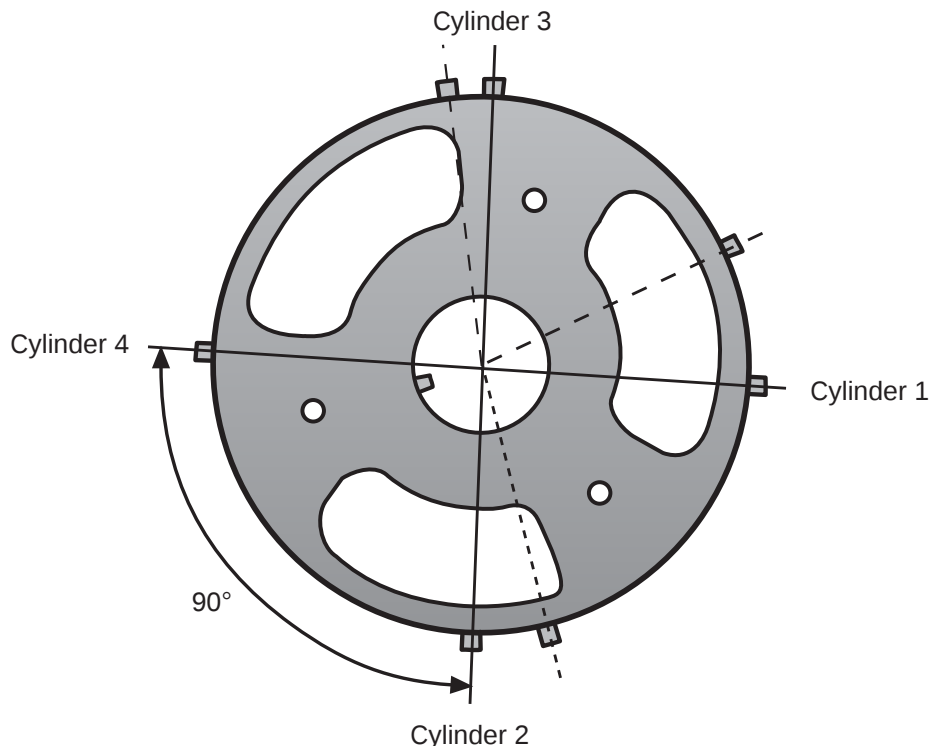
## Cylinder recognition when starting the engine

When starting the engine, the Diesel Direct Fuel Injection Engine Control Module J248 must determine which cylinder is in the compression stroke in order to activate the correct pump/injector valve. To achieve this, it evaluates the signal generated by the Camshaft Position Sensor G40, which scans the teeth of the camshaft sensor wheel to determine the camshaft position.

### Camshaft sensor wheel

Since the camshaft executes one 360-degree revolution per working cycle, there is a tooth for each individual cylinder on the sensor wheel. These teeth are spaced 90 degrees apart.

To differentiate between cylinders, the sensor wheel has an additional tooth with different spacing for each of cylinders 1, 2, and 3.



SSP209/094

# Engine Management

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## Function

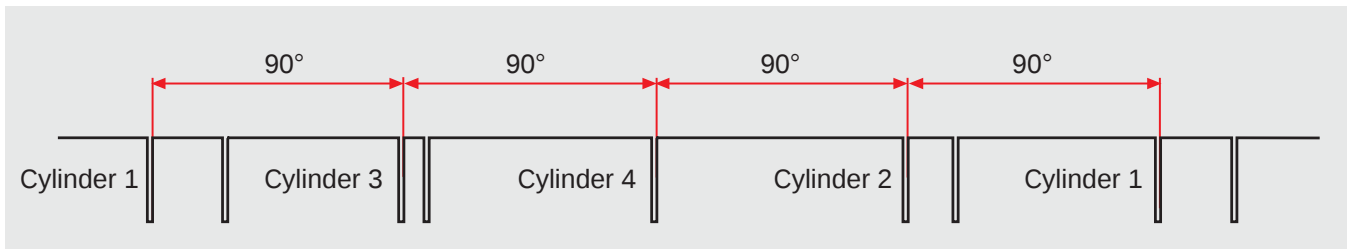
Each time a tooth passes the Camshaft Position Sensor G40, a Hall-effect voltage is induced and transmitted to the Diesel Direct Fuel Injection Engine Control Module J248.

Because the teeth are spaced at different distances apart, the induced voltage occurs at different time intervals.

From this, the Diesel Direct Fuel Injection Engine Control Module J248 determines the relative positions of the cylinders and uses this information to control the solenoid valves for pump/injectors.

Refer to “Quick-Start Function” (page 34).

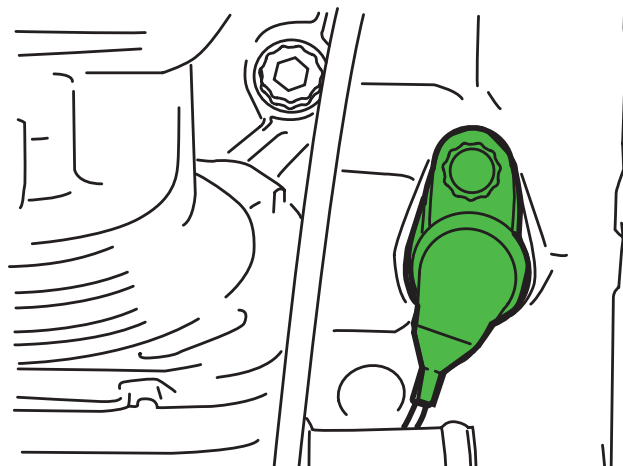
## Signal Pattern, Camshaft Position Sensor G40



SSP209/095a

## Engine Speed Sensor G28

The Engine Speed Sensor G28 is an inductive sensor. It is attached to the cylinder block.



SSP209/056

## Engine speed sensor wheel

The Engine Speed Sensor G28 scans a 60-2-2 sensor wheel attached to the crankshaft. This means that the sensor wheel has 56 teeth with two gaps the width of two teeth each on its circumference.

These gaps are 180 degrees apart and serve as reference points for determining the crankshaft position.

## Signal application

The signal generated by the Engine Speed Sensor G28 provides both the engine speed and the exact position of the crankshaft.

The injection point and the injection quantity are calculated using this information.

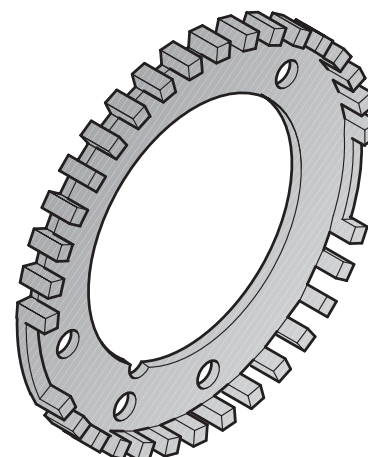
## Effects of signal failure

If the signal of the Engine Speed Sensor G28 fails, the engine is switched off.

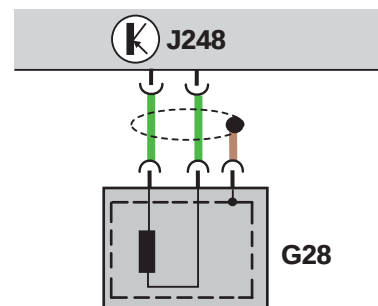
## Electrical circuit

G28 Engine Speed Sensor

J248 Diesel Direct Fuel Injection Engine Control Module



SSP209/085



SSP209/057

# Engine Management

## Quick-Start Function

To allow the engine to be started quickly, the Diesel Direct Fuel Injection Engine Control Module J248 evaluates the signals generated by the Camshaft Position Sensor G40 and the Engine Speed Sensor G28.

The Diesel Direct Fuel Injection Engine Control Module J248 uses the signal that the Camshaft Position Sensor G40 generates to determine the relative positions of the pistons in the cylinders when starting the engine.

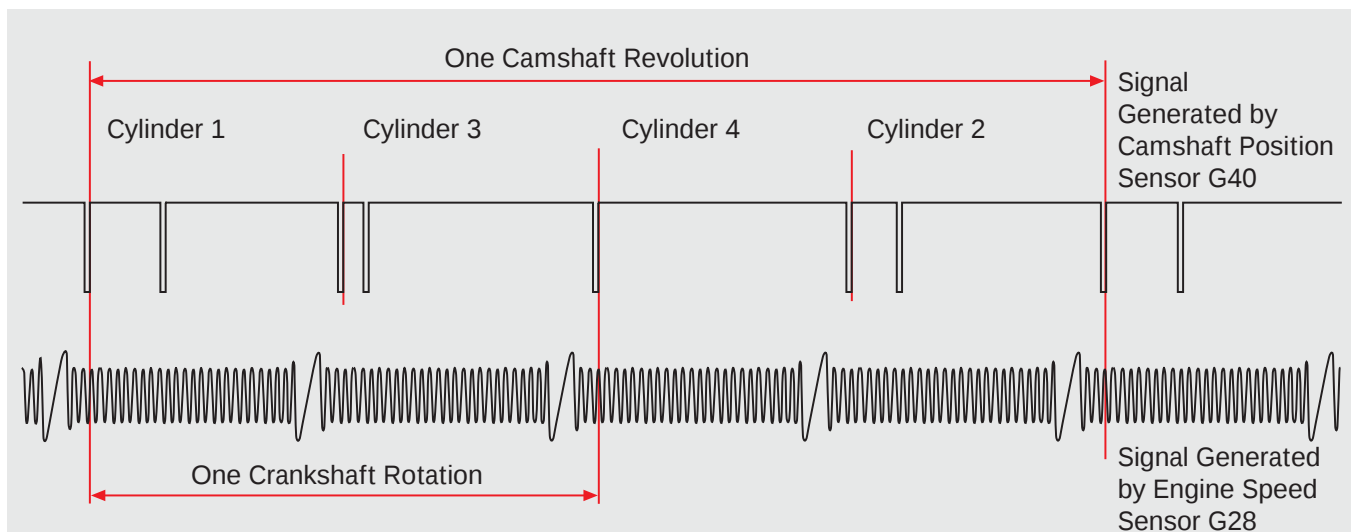
Because there are two gaps on the crankshaft sensor wheel, the Diesel Direct Fuel Injection Engine Control Module J248 receives a usable reference signal from the Engine Speed Sensor G28 after only half a turn of the crankshaft.

By interpreting the signals from these two sensors, the Diesel Direct Fuel Injection Engine Control Module J248 determines the position of the crankshaft in relation to the camshaft and thus the positions of the pistons in the cylinders at an early stage.

With this information, it can activate the correct solenoid valve at the proper time to initiate the injection cycle in the next cylinder to reach the compression stage.

The quick-start function enables an early engine start because synchronization with the first cylinder is not required.

## Signal Pattern, Camshaft Position Sensor G40 and Engine Speed Sensor G28



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## Fuel Temperature Sensor G81

The Fuel Temperature Sensor G81 is located in the fuel return line between the fuel pump and the fuel cooler. It determines the current temperature of the fuel at that point.

The Fuel Temperature Sensor G81 has a negative temperature coefficient. The sensor resistance decreases with increasing fuel temperature.

### Signal application

The signal generated by the Fuel Temperature Sensor G81 is used by the Diesel Direct Fuel Injection Engine Control Module J248 to determine the fuel temperature.

This signal is needed to calculate the start of injection point and the injection quantity so that allowance can be made for the density of the fuel at different temperatures.

This signal is also used to determine the timing for switching on the fuel cooling pump.

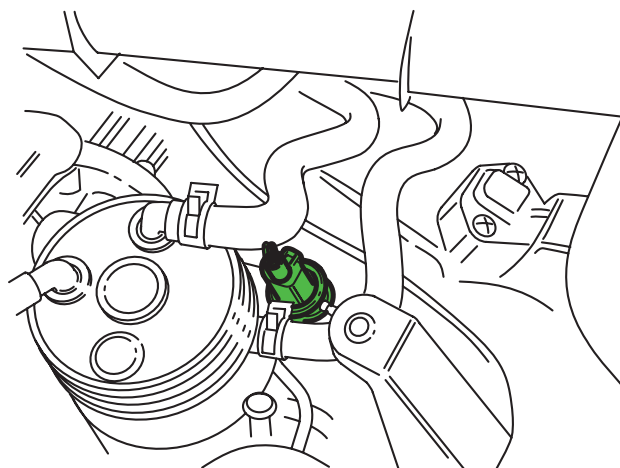
### Effects of signal failure

In the event of Fuel Temperature Sensor G81 signal failure, the Diesel Direct Fuel Injection Engine Control Module J248 calculates a substitute value from the signal generated by Engine Coolant Temperature Sensor G62.

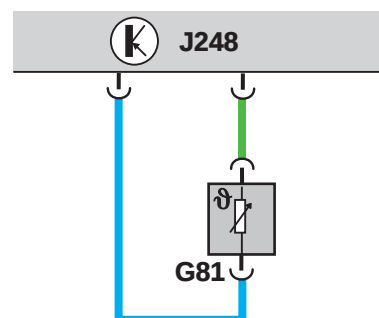
### Electrical circuit

G81 Fuel Temperature Sensor

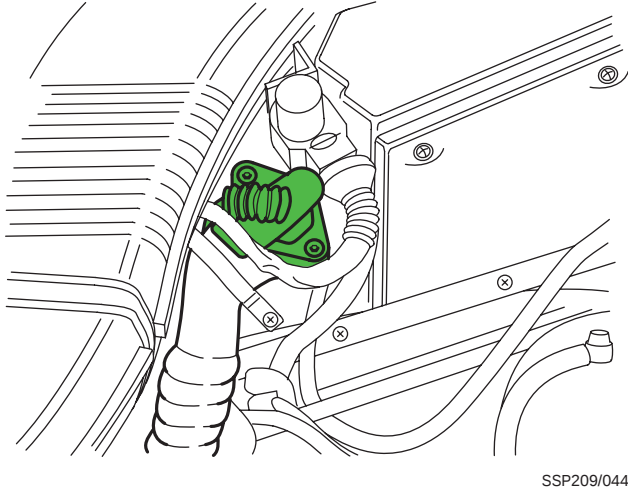
J248 Diesel Direct Fuel Injection Engine Control Module



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SSP209/058



## Mass Air Flow Sensor G70

The Mass Air Flow Sensor G70 with reverse flow recognition is located in the intake pipe. It determines the intake air mass.

The opening and closing actions of the valve produce reverse flows in the induced air mass in the intake pipe.

The Mass Air Flow Sensor G70 recognizes and makes allowance for the returning air mass in the signal it sends to the Diesel Direct Fuel Injection Engine Control Module J248.

The air mass is accurately measured.

## Signal application

The Diesel Direct Fuel Injection Engine Control Module J248 uses the measured values from the Mass Air Flow Sensor G70 to calculate the injection quantity and the exhaust gas recirculation rate.

## Effects of signal failure

If the signal from the Mass Air Flow Sensor G70 fails, the Diesel Direct Fuel Injection Engine Control Module J248 uses a fixed substitute value.

## Engine Coolant Temperature Sensor G62

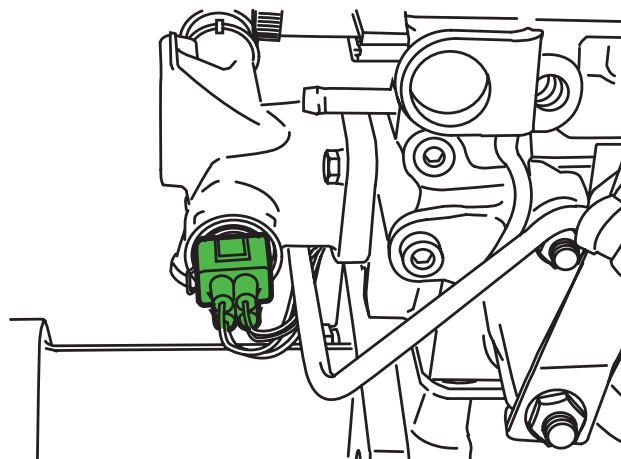
The Engine Coolant Temperature Sensor G62 is located at the coolant connection on the cylinder head. It sends information about the current coolant temperature to the Diesel Direct Fuel Injection Engine Control Module J248.

### Signal application

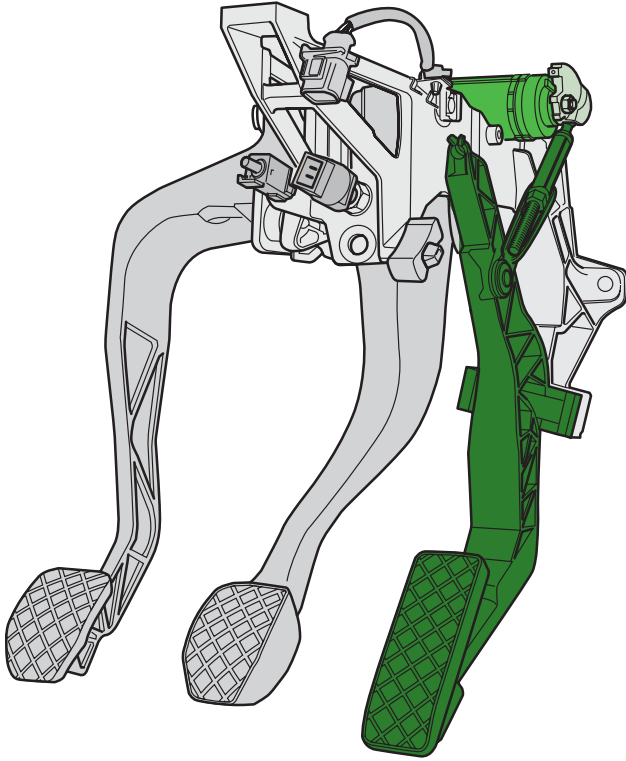
The Diesel Direct Fuel Injection Engine Control Module J248 uses the coolant temperature as a correction value for calculating the injection quantity.

### Effects of signal failure

If the signal from Engine Coolant Temperature Sensor G62 fails, the Diesel Direct Fuel Injection Engine Control Module J248 uses the signal generated by the Fuel Temperature Sensor G81 to calculate the injection quantity.



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SSP209/059

## Accelerator Pedal Sensors

The accelerator pedal sensors are integrated into a single housing and connected to the pedal by mechanical linkage.

- Throttle Position Sensor G79
- Kick Down Switch F8
- Closed Throttle Position Switch F60

## Signal application

The Diesel Direct Fuel Injection Engine Control Module J248 can recognize the position of the accelerator pedal from this signal.

In vehicles with an automatic transmission, the Kick Down Switch F8 indicates to the Diesel Direct Fuel Injection Engine Control Module J248 when the driver wants to accelerate.

## Effects of signal failure

Without the signal from Throttle Position Sensor G79, the Diesel Direct Fuel Injection Engine Control Module J248 is unable to recognize the accelerator pedal position.

The engine will only run at an increased idling speed.

## Intake Manifold Sensors

The intake manifold sensors are integrated into a single module and installed in the intake pipe.

- Manifold Absolute Pressure Sensor G71
- Intake Air Temperature Sensor G72

## Manifold Absolute Pressure Sensor G71

### Signal application

The Manifold Absolute Pressure Sensor G71 supplies a signal that is required to check the charge pressure (boost pressure).

The Diesel Direct Fuel Injection Engine Control Module J248 compares the actual measured value with the setpoint from the charge pressure map.

If the actual value deviates from the setpoint, the Diesel Direct Fuel Injection Engine Control Module J248 adjusts the charge pressure via the Wastegate Bypass Regulator Valve N75.

### Effects of signal failure

The charge pressure can no longer be regulated.

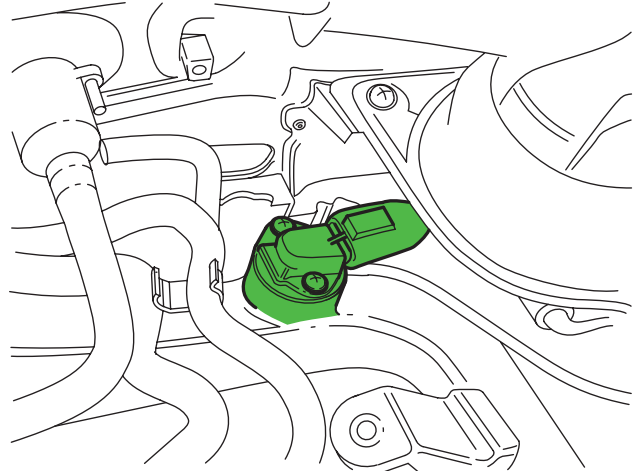
Engine performance drops.

## Intake Air Temperature Sensor G72

### Signal application

The Diesel Direct Fuel Injection Engine Control Module J248 requires the signal generated by the Intake Air Temperature Sensor G72 as a correction value for computing the charge pressure.

It can then make allowance for the effect of temperature on the density of the charge air.



SSP209/045

### Effects of signal failure

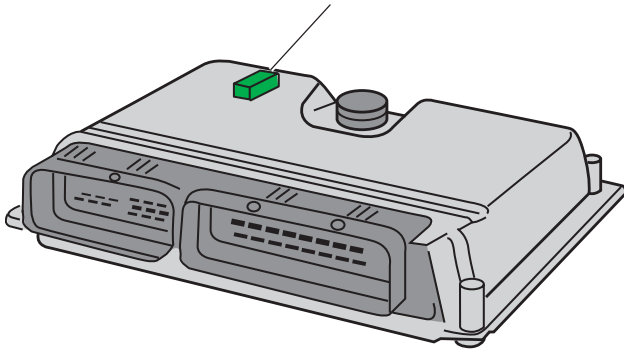
If the Intake Air Temperature Sensor G72 signal fails, the Diesel Direct Fuel Injection Engine Control Module J248 uses a fixed substitute value to calculate the charge pressure.

This can result in a drop in engine performance.

# Engine Management

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Barometric Pressure Sensor F96



SSP209/061

## Barometric Pressure Sensor F96

The Barometric Pressure Sensor F96 is located inside the Diesel Direct Fuel Injection Engine Control Module J248.

### Signal application

The Barometric Pressure Sensor F96 sends the current ambient air pressure to the Diesel Direct Fuel Injection Engine Control Module J248.

This value is dependent on the vehicle's geographical altitude.

With this signal the Diesel Direct Fuel Injection Engine Control Module J248 can carry out an altitude correction for charge pressure control and exhaust gas recirculation.

### Effects of signal failure

Black smoke occurs at altitude.

## Clutch Vacuum Vent Valve Switch F36

The Clutch Vacuum Vent Valve Switch F36 is located at the foot controls on vehicles with manual transmissions.

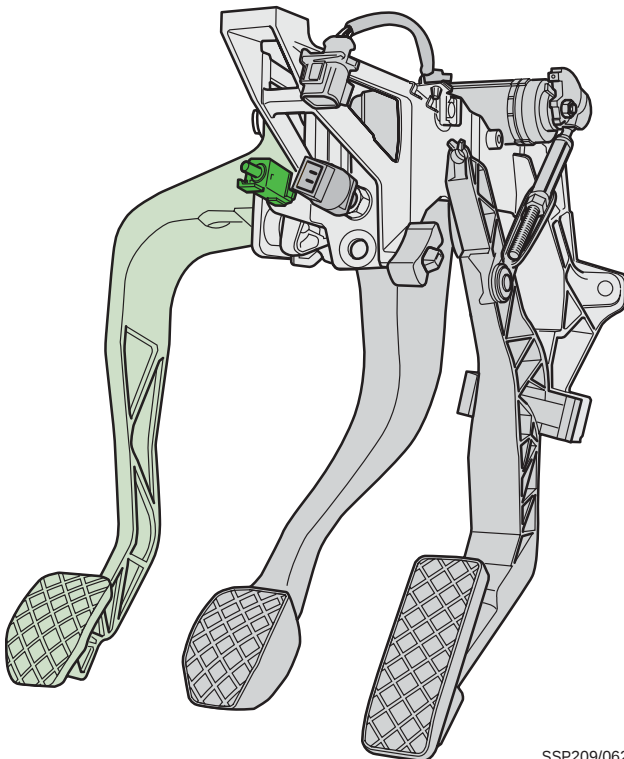
### Signal application

The Diesel Direct Fuel Injection Engine Control Module J248 determines from this signal whether the clutch is engaged or disengaged.

When the clutch is engaged, injection quantity is reduced briefly to prevent engine shudder when shifting gears.

### Effects of signal failure

If the signal from the Clutch Vacuum Vent Valve Switch F36 fails, engine shudder can occur when shifting gears.



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## Brake Pedal Sensors

The brake pedal sensors are integrated into a single module that is mounted on the brake pedal bracket.

- Brake Light Switch F
- Brake Pedal Switch F47

## Signal application

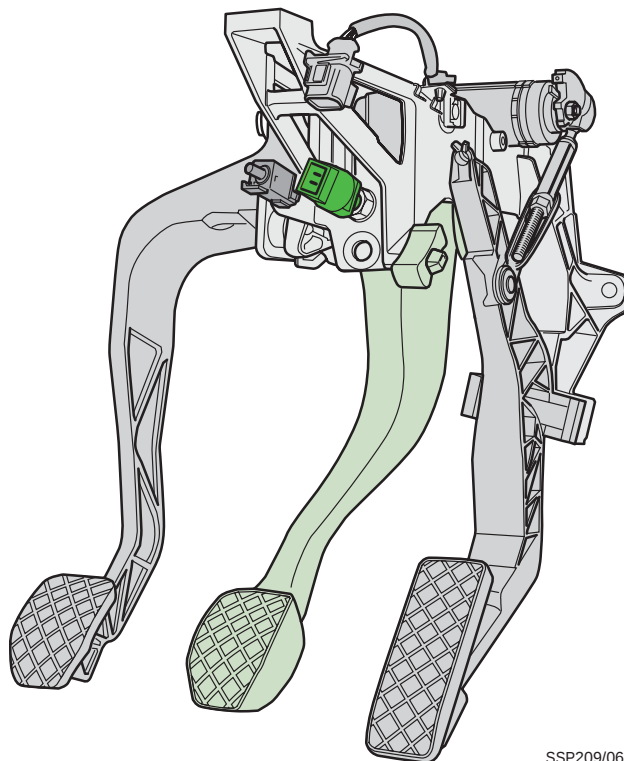
Both switches supply the Diesel Direct Fuel Injection Engine Control Module J248 with the “brake activated” signal.

The engine speed is regulated when the brake is activated for safety reasons, since the Throttle Position Sensor G79 could be defective.

## Effects of signal failure

If one of the two switches fails, Diesel Direct Fuel Injection Engine Control Module J248 reduces the fuel quantity.

Engine performance drops.

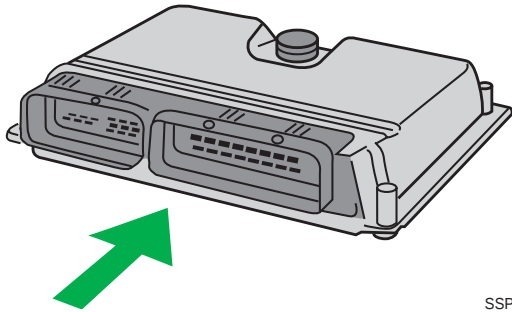


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# Engine Management

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## Additional Input Signals



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### Road speed signal

The Diesel Direct Fuel Injection Engine Control Module J248 receives the road speed signal from the vehicle speed sensor.

This signal is used to calculate various functions, including cooling fan run-on and engine shudder damping when shifting gears.

It is also used to check the cruise control system for proper functioning.

### Air conditioner compressor ready

The air conditioner switch sends Diesel Direct Fuel Injection Engine Control Module J248 a signal indicating that the air conditioner compressor will shortly be switched on.

This enables the Diesel Direct Fuel Injection Engine Control Module J248 to increase the engine idle speed before the air conditioner compressor is switched on to prevent a sharp drop in engine speed when the compressor starts up.

### Cruise control switch

The signal generated by the cruise control switch tells the Diesel Direct Fuel Injection Engine Control Module J248 that the cruise control system has been activated.

### Three-phase AC generator terminal DF

The signal supplied by generator terminal DF indicates the load state of the three-phase AC generator to the Diesel Direct Fuel Injection Engine Control Module J248.

Depending on available capacity, the Diesel Direct Fuel Injection Engine Control Module J248 can switch on one, two, or three Glow Plugs (Coolant) Q7 of the coolant auxiliary heater via the Relay for Preheating Coolant, Low Heat Output J359 and the Relay for Preheating Coolant, High Heat Output J360.

### CAN data bus

The Diesel Direct Fuel Injection Engine Control Module J248, the ABS Control Module with EDL/ASR/ESP J104, and the Transmission Control Module J217 interchange information along a CAN data bus.

## Actuators

### Pump/Injector Solenoid Valves

The 1.9-liter TDI engine with the new pump injection system uses four pump/injector solenoid valves:

- Valve for Pump/Injector, Cylinder 1 N240
- Valve for Pump/Injector, Cylinder 2 N241
- Valve for Pump/Injector, Cylinder 3 N242
- Valve for Pump/Injector, Cylinder 4 N243

The pump/injector solenoid valves are attached to their pump/injectors with a cap nut.

The Diesel Direct Fuel Injection Engine Control Module J248 regulates the start of injection points and injection quantities of the pump/injectors by activating their solenoid valves at the appropriate times.

### Start of injection point

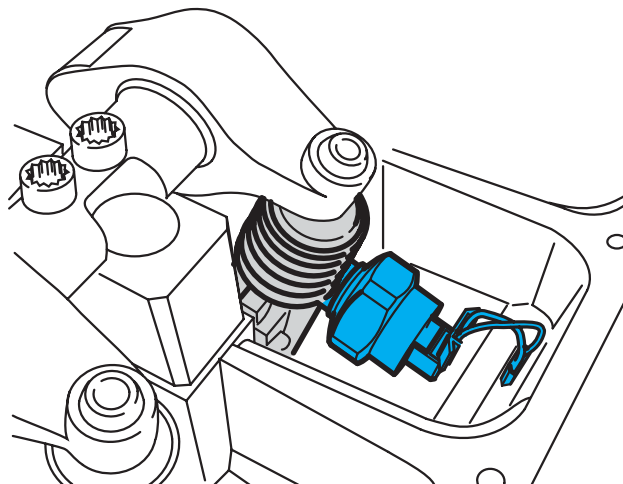
As soon as the Diesel Direct Fuel Injection Engine Control Module J248 activates a pump/injector solenoid valve, the magnetic coil presses the solenoid valve needle down into the valve seat and closes off the path from the fuel supply line to the high-pressure chamber of the pump/injector.

The injection cycle then begins.

### Injection quantity

The injection quantity is determined by the length of time that the solenoid valve is activated.

Fuel is injected into the combustion chamber as long as the pump/injector solenoid valve is closed.



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# Engine Management

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## Effects of failure

If a pump/injector solenoid valve fails, the engine will not run smoothly and performance will be reduced.

The pump/injector solenoid valve has a dual safety function.

If the valve stays open, pressure cannot build up in the pump/injector.

If the valve stays closed, the high-pressure chamber of the pump/injector can no longer be filled.

In either case, no fuel is injected into the cylinders.

## Electrical circuit

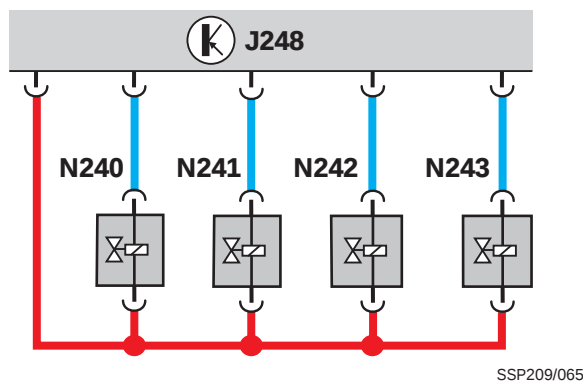
J248 Diesel Direct Fuel Injection Engine Control Module

N240 Valve for Pump/Injector, Cylinder 1

N241 Valve for Pump/Injector, Cylinder 2

N242 Valve for Pump/Injector, Cylinder 3

N243 Valve for Pump/Injector, Cylinder 4



## Pump/injector solenoid valve monitoring

The Diesel Direct Fuel Injection Engine Control Module J248 monitors the electrical current that actuates the solenoid valves at the pump/injectors.

This provides feedback to the Diesel Direct Fuel Injection Engine Control Module J248 of the actual point in time when injection begins.

The Diesel Direct Fuel Injection Engine Control Module J248 uses this feedback to regulate the beginning of injection periods (BIP) during subsequent combustion cycles and to detect malfunctions of the pump/injector solenoid valves.

Start of injection is initiated when the pump/injector solenoid valve is actuated.

Actuating current applied to a pump/injector solenoid valve creates a magnetic field. As the applied current intensity increases, the valve closes; the magnetic coil presses the solenoid valve needle into its valve seat. This closes off the path from the fuel supply line to the pump/injector high-pressure chamber and the injection period begins.

As the solenoid valve needle contacts its valve seat, the distinctive signature of an alternately dropping and rising current flow is detected by the Diesel Direct Fuel Injection Engine Control Module J248. This point is called the beginning of injection period (BIP). It indicates the complete closure of the pump/injector solenoid valve and the starting point of fuel delivery.

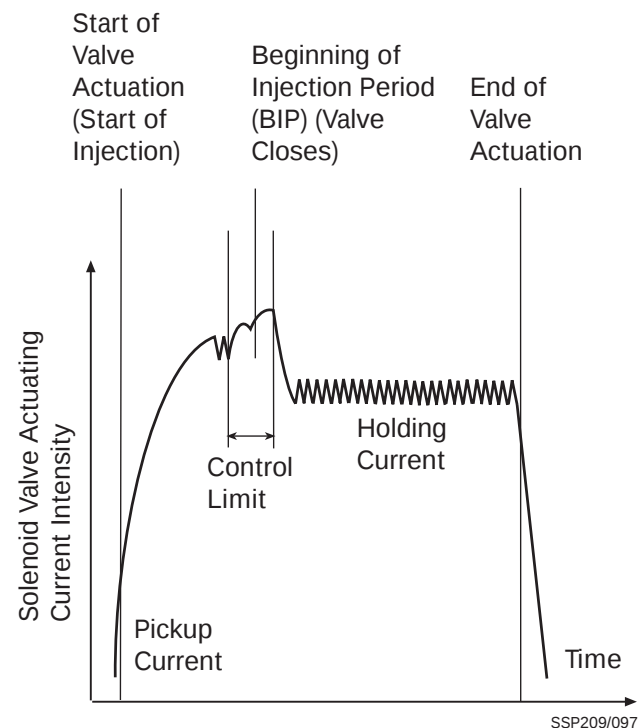


**“Start of injection”** is the point in time when the actuating current to the pump/injector solenoid valve is initiated.

**“Beginning of injection period (BIP)”** is the point in time when the solenoid valve needle contacts the valve seat.

With the solenoid valve closed, a holding current is maintained at a constant level by the Diesel Direct Fuel Injection Engine Control Module J248 to keep it closed. Once the required time period for fuel delivery has elapsed, the actuating current is switched off and the solenoid valve opens.

## Current Pattern - Pump/Injector Solenoid Valve



The actual moment at which the pump/injector solenoid valve closes (BIP) is used by the Diesel Direct Fuel Injection Engine Control Module J248 to calculate the point of actuation for the next injection period.

If the actual BIP deviates from the mapped details stored in the Diesel Direct Fuel Injection Engine Control Module J248, it will correct the point of valve actuation (start of injection) for the next combustion cycle.

To detect pump/injector solenoid valve faults, the Diesel Direct Fuel Injection Engine Control Module J248 evaluates the BIP position from the current flow pattern. If there are no faults, BIP will be within the control limit. If this is not the case, the valve is faulty.

## **Effects of failure**

If a fault is detected at the solenoid valve, start of injection is determined based on fixed values from the control map.

Regulation is no longer possible and performance is impaired.

## **Example**

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

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

“BIP below control limit”

## Change-Over Valve for Intake Manifold Flap N239

The Change-Over Valve for Intake Manifold Flap N239 is located in the engine compartment, in the vicinity of the Mass Air Flow Sensor G70.

It switches the vacuum for actuating the intake manifold flap in the intake pipe. This stops the engine shuddering when the ignition is turned off.

Diesel engines have a high compression ratio.

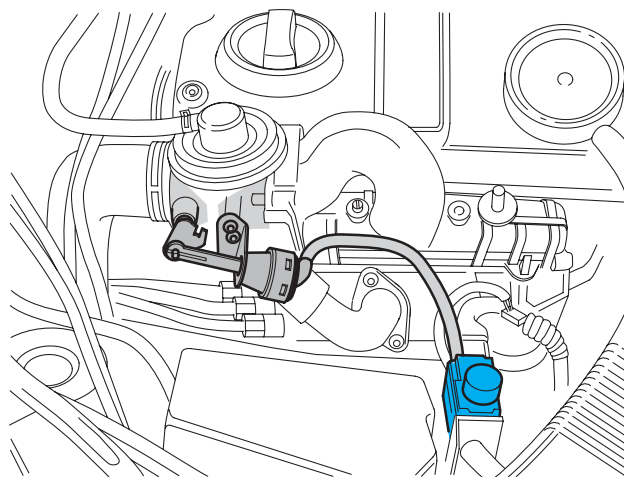
The engine shudders when the ignition is turned off because of the high compression pressure of the induced air.

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

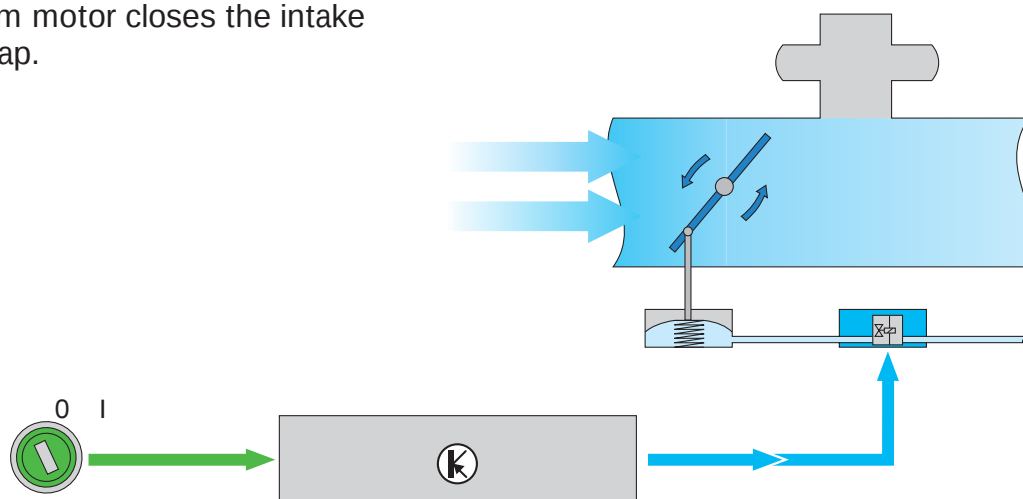
## Function

If the engine is turned off, the Diesel Direct Fuel Injection Engine Control Module J248 sends a signal to the Change-Over Valve for Intake Manifold Flap N239, which then switches the vacuum for the vacuum motor.

The vacuum motor closes the intake manifold flap.



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# Engine Management

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## Effects of failure

If the Change-Over Valve for Intake Manifold Flap N239 fails, the intake manifold flap stays open.

The tendency of the engine to shudder when switched off will increase.

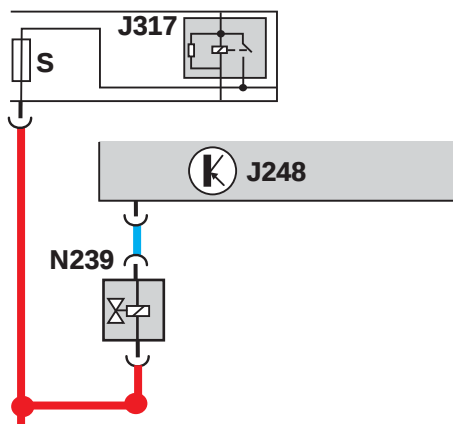
## Electrical circuit

J217 Transmission Control Module

J248 Diesel Direct Fuel Injection Engine Control Module

N239 Change-Over Valve for Intake Manifold Flap

S Fuse



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## Relay for Pump, Fuel Cooling J445

The Relay for Pump, Fuel Cooling J445 is located on the engine control module mounting bracket.

It is activated by the Diesel Direct Fuel Injection Engine Control Module J248 at a fuel temperature of 158°F (70°C) and switches the working current for the Pump for Fuel Cooler V166.

### Effects of failure

If the Relay for Pump, Fuel Cooling J445 fails, the heated fuel flowing back from the pump/injectors to the fuel tank will not be cooled.

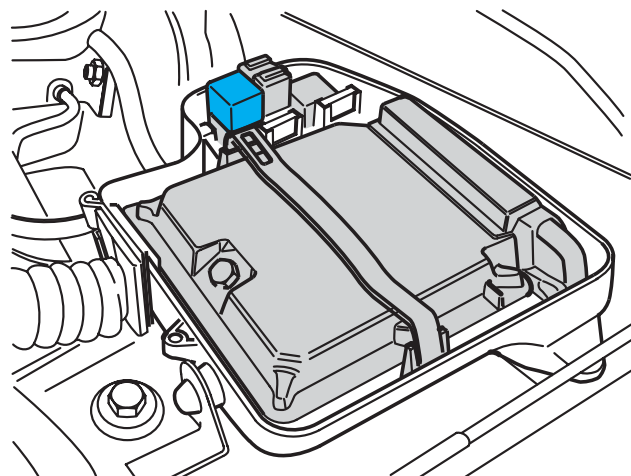
The fuel tank and the Sender for Fuel Gage G can be damaged.

### Electrical circuit

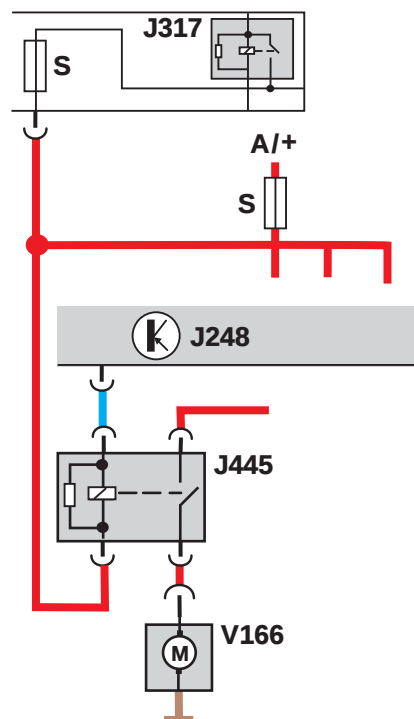
- J248 Diesel Direct Fuel Injection Engine Control Module
- J317 Power Supply (Terminal 30, B+) Relay
- J445 Relay for Pump, Fuel Cooling
- S Fuse
- V166 Pump for Fuel Cooler



The Output Check Diagnosis function in the self-diagnosis can be used to check whether the Relay for Pump, Fuel Cooling J445 has been activated by the Diesel Direct Fuel Injection Engine Control Module J248.



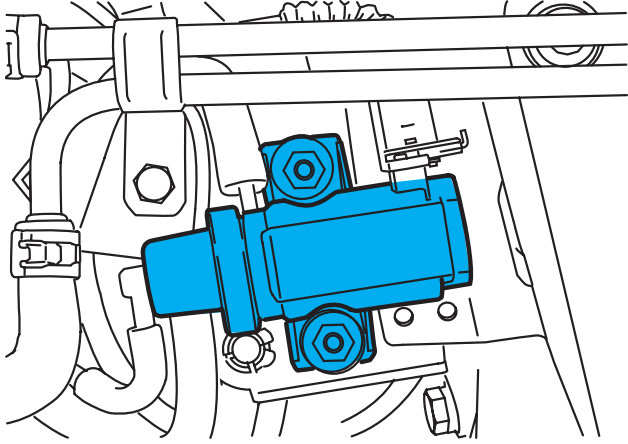
SSP209/071



SSP209/072

# Engine Management

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## **Wastegate Bypass Regulator Valve N75**

The engine has a variable turbine geometry for optimally adapting the charge pressure to the actual driving conditions.

To regulate the charge pressure, the vacuum in the vacuum unit for turbocharger vane adjustment is set depending on the pulse duty factor.

The Wastegate Bypass Regulator Valve N75 is activated by the Diesel Direct Fuel Injection Engine Control Module J248.

## **Effects of failure**

If the Wastegate Bypass Regulator Valve N75 fails, the vacuum unit reverts to atmospheric pressure.

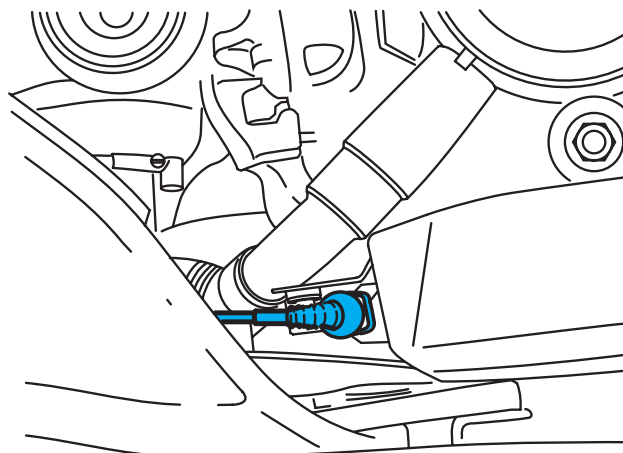
As a result, charge pressure is lower and engine performance is impaired.

## **EGR Vacuum Regulator Solenoid Valve N18**

The EGR Vacuum Regulator Solenoid Valve N18 enables the exhaust gas recirculation system to mix a portion of the exhaust gases with the fresh air supplied to the engine.

This lowers the combustion temperature and reduces the formation of oxides of nitrogen.

To control the quantity of exhaust gases returned for combustion, the Diesel Direct Fuel Injection Engine Control Module J248 activates the EGR Vacuum Regulator Solenoid Valve N18 with duty cycles based on internal control maps.



SSP209/075

### **Effects of failure**

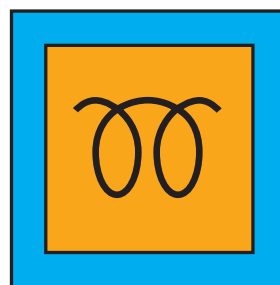
Engine performance is lower and exhaust gas recirculation is not assured.

## **Glow Plug Indicator Light K29**

The Glow Plug Indicator Light K29 is located in the instrument cluster.

It has the following tasks:

- It signals to the driver that the pre-starting glow phase is in progress. In this case, it is lit continuously.
- If a component with self-diagnostic capability becomes faulty, the warning lamp flashes.



SSP209/077

### **Effects of failure**

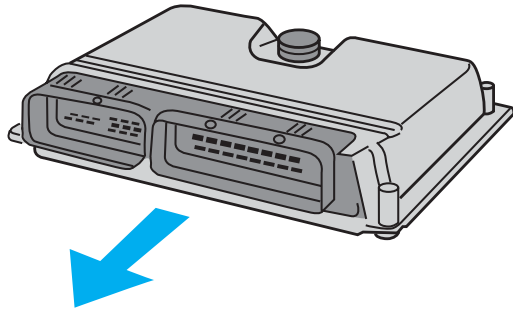
The Glow Plug Indicator Light K29 comes on and does not flash.

A fault message is stored to the fault memory.

# Engine Management

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## Additional Output Signals



SSP209/084

### Coolant auxiliary heater

Thanks to its high efficiency, the 1.9-liter TDI engine with pump injection system develops so little heat that sufficient heat output may not be available in certain circumstances.

In countries with cold climates, an electrical auxiliary heater is used to heat the coolant at low temperatures.

The coolant auxiliary heater is comprised of three Glow Plugs (Coolant) Q7. They are installed to the coolant connection on the cylinder head.

The Diesel Direct Fuel Injection Engine Control Module J248 uses the coolant auxiliary heater signal to activate the relays for low and high heat output.

Either one, two, or all three Glow Plugs (Coolant) Q7 are switched on depending on the available capacity of the three-phase AC generator.

### Engine speed

This signal provides information on engine speed for the tachometer in the instrument cluster.

### Cooling fan run-on

The run-on period of the cooling fan is controlled according to a characteristic curve stored in the Diesel Direct Fuel Injection Engine Control Module J248.

It is calculated from the current coolant temperature and the load state of the engine during the previous driving cycle. The Diesel Direct Fuel Injection Engine Control Module J248 uses this signal to activate the cooling fan relay.

### Air conditioner compressor cut-off

To reduce engine load, the Diesel Direct Fuel Injection Engine Control Module J248 switches the air conditioner compressor off under the following conditions:

- After every starting cycle (for approximately six seconds).
- During rapid acceleration from low engine speeds.
- At coolant temperatures in excess of 248°F (120°C).
- In the emergency running program.

### Fuel consumption signal

This signal provides information on fuel consumption for the multifunctional display in the instrument cluster.

# Glow Plug System

## Glow Plug System

The glow plug system makes it easier to start the engine at low outside temperatures. It is activated by the Diesel Direct Fuel Injection Engine Control Module J248 at coolant temperatures below 48°F (9°C).

The Glow Plug Relay J52 is activated by the Diesel Direct Fuel Injection Engine Control Module J248. The Glow Plug Relay J52 then switches on the working current for the Glow Plugs Q6.

### Function

The glow process is divided into two phases, the glow period and the extended glow period.

### Glow Period

The glow plugs are activated when the ignition is switched on and outside temperature is below 48°F (9°C). The Glow Plug Indicator Light K29 will light up.

Once the glow plug period has elapsed, the Glow Plug Indicator Light K29 will go out and the engine can be started.

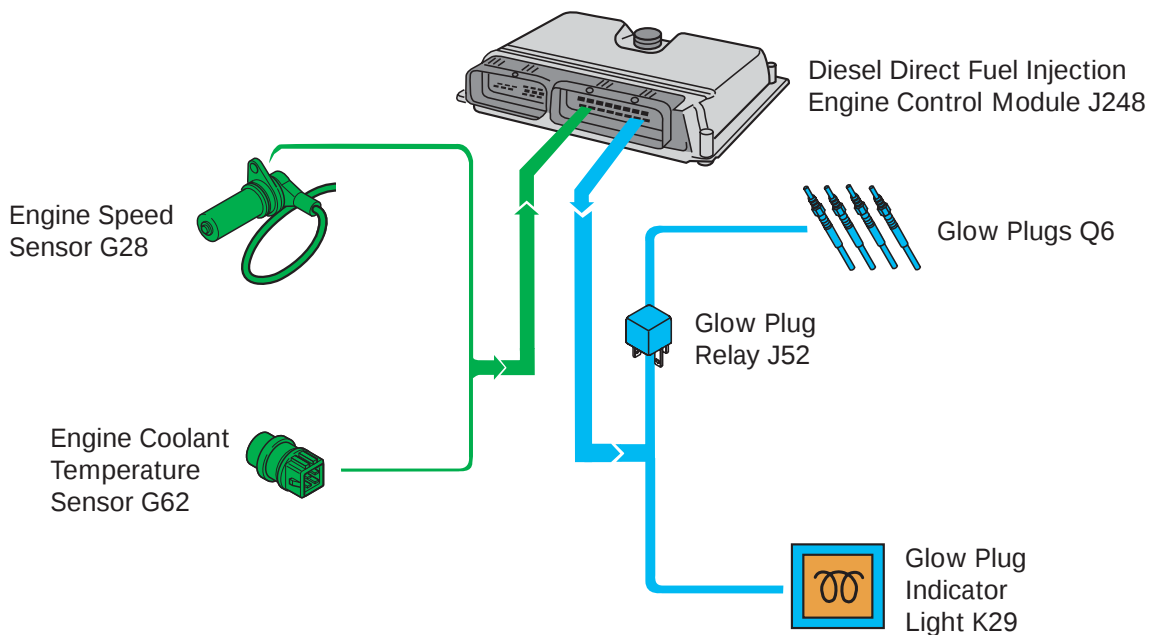
### Extended Glow Period

The extended glow period takes place whenever the engine is started, regardless of whether or not it is preceded by a glow period.

This reduces combustion noise, improves idling quality and reduces hydrocarbon emission.

The extended glow phase lasts no more than four minutes and is interrupted when the engine speed rises above 2500 rpm.

## Glow Plug System Overview



SSP209/099

# Functional Diagram

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## EDC 16 Functional Diagram for 1.9-Liter TDI Engine

### Components

|      |                                                    |
|------|----------------------------------------------------|
| E45  | Cruise Control Switch                              |
| F    | Brake Light Switch                                 |
| F8   | Kick Down Switch                                   |
| F36  | Clutch Vacuum Vent Valve Switch                    |
| F47  | Brake Pedal Switch                                 |
| F60  | Closed Throttle Position Switch                    |
| G28  | Engine Speed Sensor                                |
| G40  | Camshaft Position Sensor                           |
| G62  | Engine Coolant Temperature Sensor                  |
| G70  | Mass Air Flow Sensor                               |
| G71  | Manifold Absolute Pressure Sensor                  |
| G72  | Intake Air Temperature Sensor                      |
| G79  | Throttle Position Sensor                           |
| G81  | Fuel Temperature Sensor                            |
| J52  | Glow Plug Relay                                    |
| J248 | Diesel Direct Fuel Injection Engine Control Module |
| J317 | Power Supply (Terminal 30, B+) Relay               |
| J359 | Relay for Preheating Coolant, Low Heat Output      |
| J360 | Relay for Preheating Coolant, High Heat Output     |
| J445 | Relay for Pump, Fuel Cooling                       |
| N18  | EGR Vacuum Regulator Solenoid Valve                |
| N75  | Wastegate Bypass Regulator Valve                   |
| N239 | Change-Over Valve for Intake Manifold Flap         |
| N240 | Valve for Pump/Injector, Cylinder 1                |
| N241 | Valve for Pump/Injector, Cylinder 2                |
| N242 | Valve for Pump/Injector, Cylinder 3                |
| N243 | Valve for Pump/Injector, Cylinder 4                |
| Q6   | Glow Plugs (Engine)                                |
| Q7   | Glow Plugs (Coolant)                               |
| S    | Fuse                                               |
| V166 | Pump for Fuel Cooler                               |

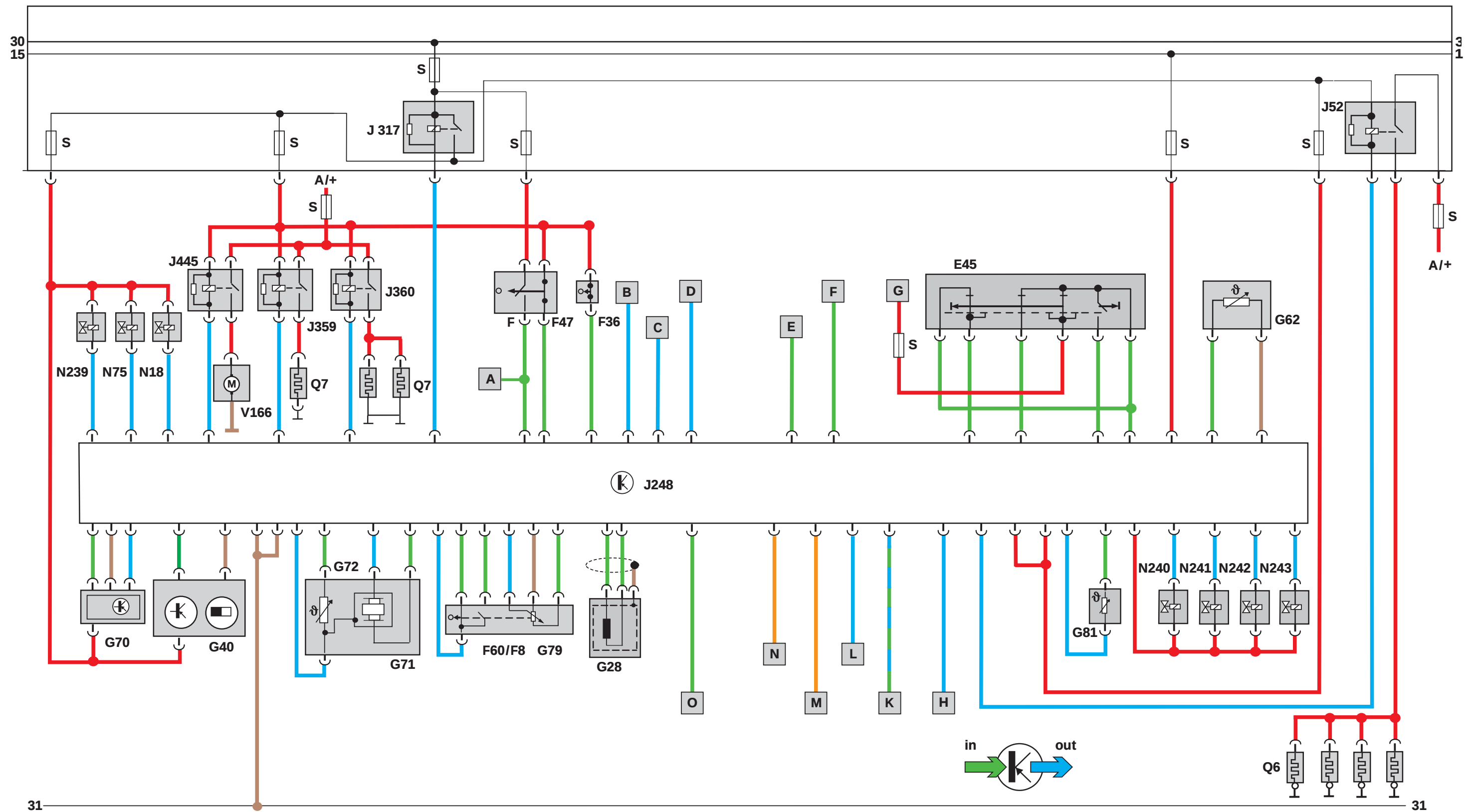
### Additional Signals

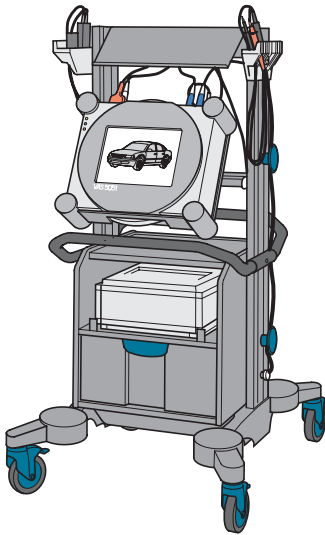
|   |                                      |
|---|--------------------------------------|
| A | Brake Lights                         |
| B | Fuel Consumption Signal              |
| C | Engine Speed Signal                  |
| D | Air Conditioner Compressor Cut-Off   |
| E | Air Conditioner Compressor Readiness |
| F | Road Speed Signal                    |
| G | Cruise Control Switch Voltage Supply |
| H | Cooling Fan Run-On                   |
| K | Diagnosis and Immobilizer Wire       |
| L | Glow Period Control                  |
| M | Drivetrain CAN Data Bus (Low)        |
| N | Drivetrain CAN Data Bus (High)       |
| O | Three-Phase AC Generator Terminal DF |

### Color Coding

|                                                                                     |                |
|-------------------------------------------------------------------------------------|----------------|
|  | Input Signal   |
|  | Output Signal  |
|  | Positive       |
|  | Ground         |
|  | CAN Data Bus   |
|  | Bi-directional |

## Functional Diagram





SSP209/082

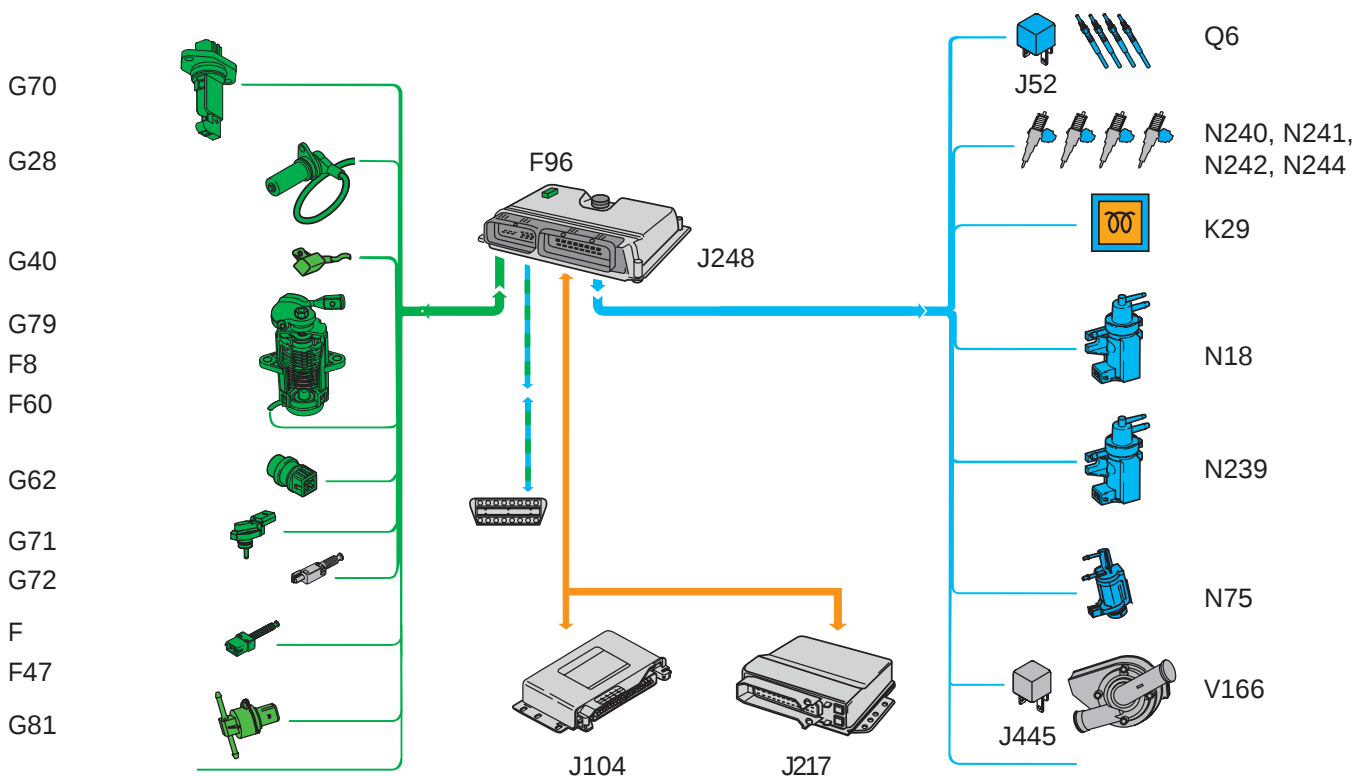
## Self-Diagnosis

The following functions can be read out using the Vehicle Diagnosis, Test and Information System VAS 5051:

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

## Function 02 – Interrogate fault memory

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



SSP209/081

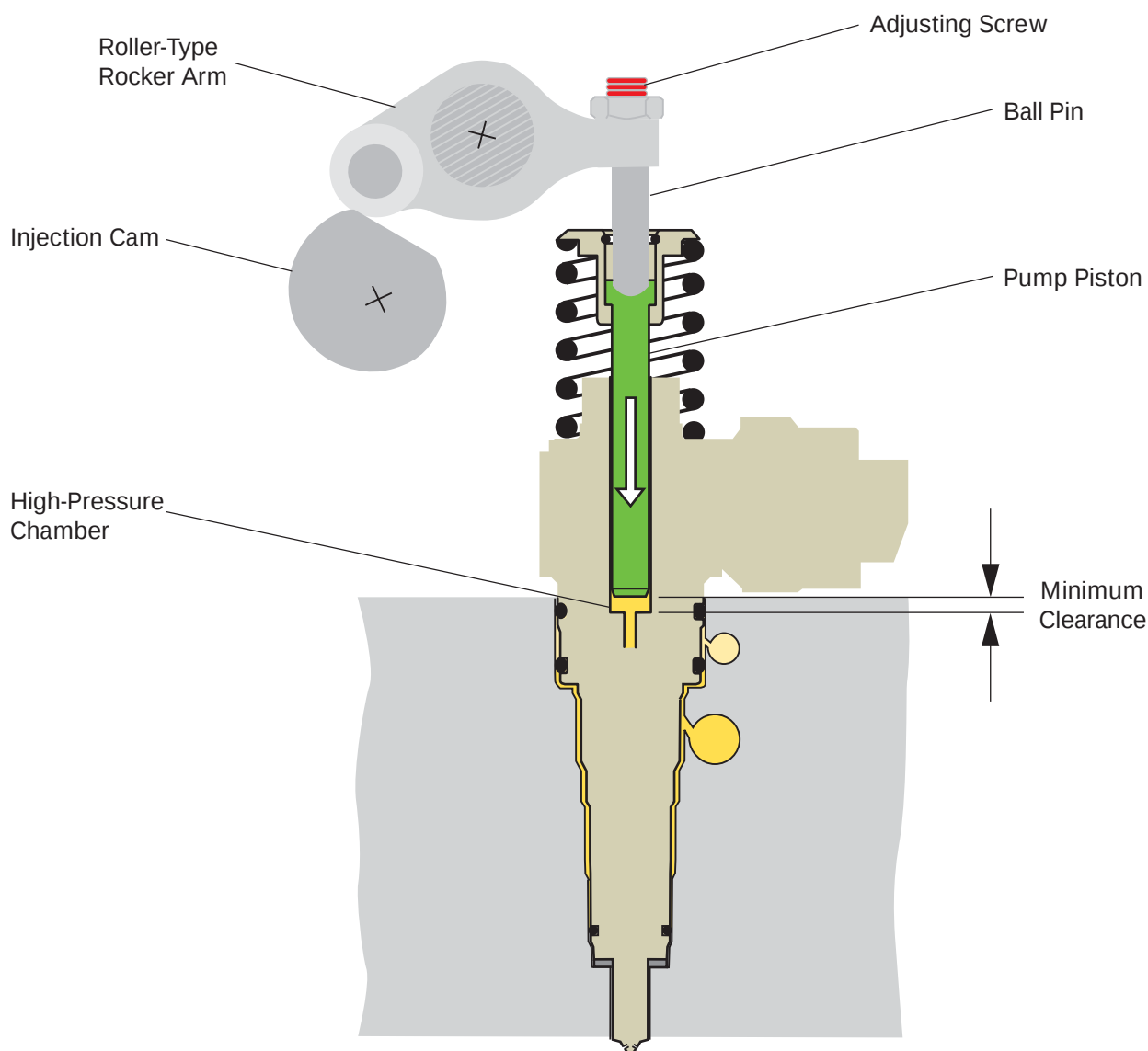
## Pump/Injector Adjustment

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

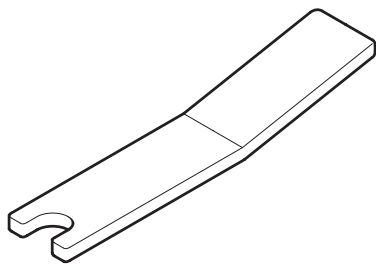
This adjustment prevents the pump piston from knocking against the base of the high-pressure chamber due to heat expansion.



For a complete description of this adjustment procedure, refer to the Repair Manual.



SSP209/098



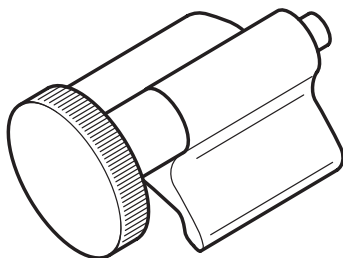
SSP209/090a

## Special Tools

### Marking Plate

T 10008

Holds the hydraulic toothed belt tensioner in place when installing and removing the toothed belt.

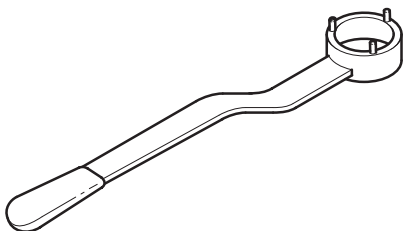


SSP209/090b

### Crankshaft Stop

T 10050

Holds the crankshaft in place at the crankshaft gear when adjusting the port timing.

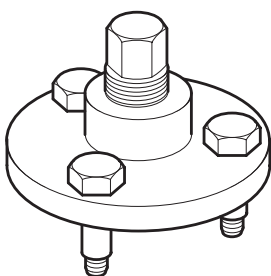


SSP209/090c

### Camshaft Gear Counter-Holder

T 10051

Camshaft gear installation.

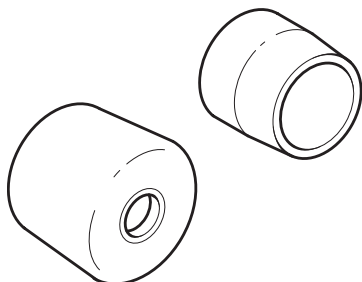


SSP209/090d

### Camshaft Gear Puller

T 10052

Camshaft gear removal from the tapered end of the camshaft.



SSP209/090e

### Crankshaft Sealing Ring Assembly Fixture

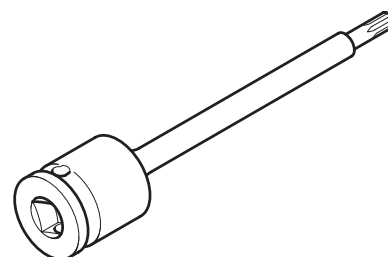
T 10053

Guide sleeve and compression sleeve for installing the crankshaft sealing ring.

## Socket Insert

T 10054

Pump/injector clamping block fastener installation.

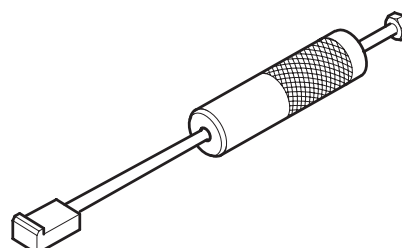


SSP209/090f

## Pump/Injector Puller

T 10055

Pump/injector removal from the cylinder head.

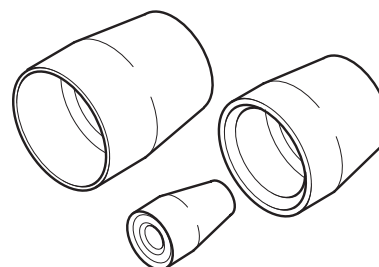


SSP209/090g

## Pump/Injector O-Ring Assembly Sleeves

T 10056

O-ring installation on the pump/injectors.



SSP209/090h

## Shackle

T 10059

This shackle is used to remove and install the engine in the Passat. The engine is moved into position using this shackle in combination with lifting gear 2024A.

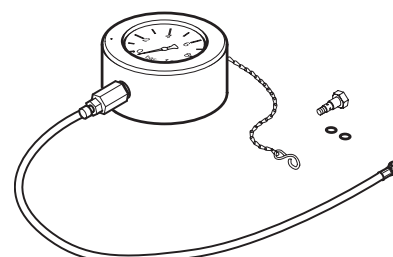


SSP209/090k

## Pressure Gauge

VAS 5187

Fuel pressure measurement at the supply line to the fuel pump.



SSP209/090i

# Notes

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# Knowledge Assessment

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An on-line Knowledge Assessment (exam) is available for this Self-Study Program.

The Knowledge Assessment may or may not be required for Certification.

You can find this Knowledge Assessment at:

**[www.vwwebsource.com](http://www.vwwebsource.com)**

From the vwwebsource.com Homepage, do the following:

- Click on the Certification tab
- Type the course number in the Search box
- Click “Go!” and wait until the screen refreshes
- Click “Start” to begin the Assessment

For Assistance, please call:

**Certification Program Headquarters**

**1 – 877 – CU4 – CERT  
(1 – 877 – 284 – 2378)**

**(8:00 a.m. to 8:00 p.m. EST)**

Or, E-Mail:

**[Comments@VWCertification.com](mailto:Comments@VWCertification.com)**



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