



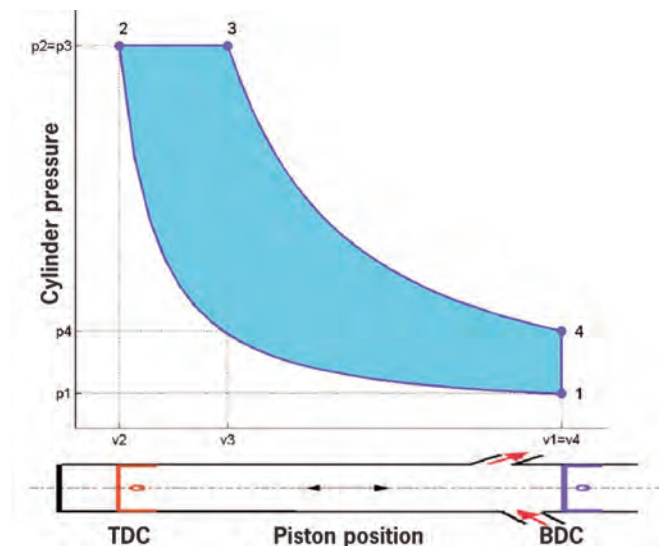
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Fuel, Exhaust & Engine Electrical

Glow and Fuel Systems

General Information

As opposed to the gasoline engine, the diesel engine does not need an ignition system because the diesel engine is a "compression ignition engine". This means that only air is aspirated and compressed with a diesel engine. Fuel is injected into the combustion chamber just ahead of TDC. The diesel self-ignites due to the temperature generated by the compression. Diesel burns more slowly than gasoline. Therefore the maximum pressure in the cylinder is maintained for longer than with a gasoline engine.



- 1 Start of compression
- 2 Piston at TDC with $p_{\max}$
- 3 Piston towards BDC at end of $p_{\max}$
- 4 Outlet valve opens

This is the reason for the high torque of the 3.0 I V6 TDI engine. Due to the viscosity and the adhesive characteristics of the diesel oil, significantly higher injection pressures are needed than for atomizing gasoline. The common rail system with piezo technology facilitates a maximum injection pressure of 29,000 psi (2,000 bar).

The highly-pressurized fuel is injected into the combustion chamber through multiple spray nozzles which have microscopic fuel outlet holes. The speed and the quality of the fuel droplets formed, as well as the speed and movement of the air, are very important factors for clean, efficient combustion. In addition to the main injection, up to two pre-injections and three post-injections are possible.

The common rail system is ideally suited to implementing these injection strategies as it is the only diesel injection system on the market that enables injection to be modulated, irrespective of the operating condition of the engine.

The injections following in quick succession can only be achieved with the very fast switching piezo injectors used, in order to facilitate:

- Smooth running
- Optimized exhaust emissions
- Active regeneration of the diesel particulate filter

Another diesel-specific system also helps to achieve the aforementioned targets - the glow system.

Glow System

As is customary for a diesel engine in a passenger car, the 3.0 I V6 TDI engine has a glow system.

The glow system consists of:

- Glow control unit
- One glow plug per cylinder
- Glow indicator light
- Retainer for glow plugs

The advantages of the glow system are as follows:

- Very fast glow plug heating time, to 1832° F. (1,000° C.) in approx. 2 seconds
- Reliable, fast starting, even at temperatures down to -11.2° F. (-24° C.)
- Reduced soot particle emissions
- Self-diagnosis capable

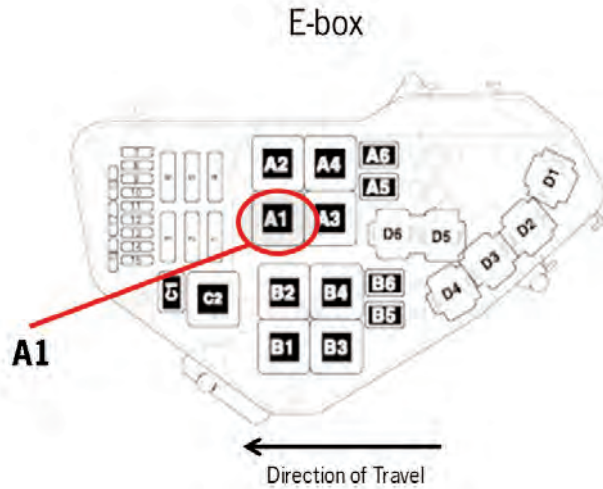
Function

The glow plugs are activated by a dedicated glow control unit which receives information from the DME control unit.

Glow Control Unit functions include:

- Switching the glow plugs with a PWM signal
- Integrated over-voltage and over-temperature shutoff
- Individual plug monitoring:
 - Detection of over-current and short-circuit in the glow circuit
 - Glow circuit over-current shut-off
 - Glow electronics diagnosis
 - Detection of an open glow circuit in the event of glow plug failure

The glow control unit is installed in the plenum panel relay box.



A1 = Glow Control Unit Position

The glow control unit energizes the glow plugs depending on:

- Engine temperature
- Engine speed
- Load
- Ambient temperature
- Operating condition of the diesel particulate filter

There are three conditions whereby the glow system can be activated by the DME control unit.

1. Preheating

Preheating takes place after the ignition has been switched on; it is dependent upon the outside temperature and the engine temperature.

Preheating the cylinders:

- Makes it possible to start the engine quickly when it is cold
- Reduces soot emissions (hydrocarbon emissions) during combustion
- Reduces ignition delay

In order to facilitate quick starting which drivers of gasoline engines are used to, the glow plugs are subject to the maximum voltage of approx. 11V for a maximum of 2 seconds. The glow plugs are activated by the glow control unit by means of pulse width modulation. Within approx. 2 seconds, the glow plugs achieve an operating temperature of approx. 1832° F. (1,000° C.) and therefore help to ensure that the required combustion chamber temperature is reached.

The hotter the glow plugs are, the shorter the pulse width of the pulse width-modulated activation voltage of the glow control unit will be. Power delivery to the glow plugs is controlled via pulse width-modulated activation in order that they reach operating temperature as quickly as possible but do not overheat. Preheating is switched off depending on the temperature but after the engine has been started at the latest.



Important!

- > The glow plugs must never be tested by applying a 12V voltage as this will destroy the glow plugs.
- > The glow system is only activated when the ignition is switched on (terminal 15). If the starter does not start immediately when terminal 50 is activated via the ignition key, it means that the preglow function is still active; this is indicated to the driver by means of the glow indicator light until the engine starts. The engine starts automatically after the initial terminal 50 signal as soon as the cylinders have been sufficiently preheated, i.e. the driver does not need to turn the ignition key again during the preglow process. With moderate coolant and ambient temperatures, the preglow time is so short that the time it takes the engine to start is comparable with gasoline engines.

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2. Post-heating

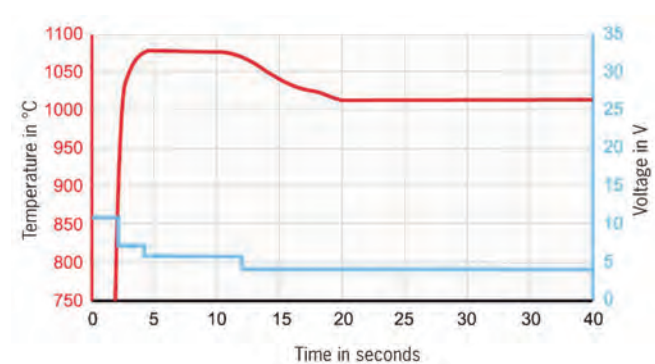
Post-heating takes place after the engine has been started, at temperatures of less than 95° F. (35° C.). Post-heating lasts until an engine temperature of 95° F. (35° C.) is achieved or for a maximum of 3 minutes.

The post-heating function enables:

- Combustion noises to be decreased
- Soot emissions to be reduced

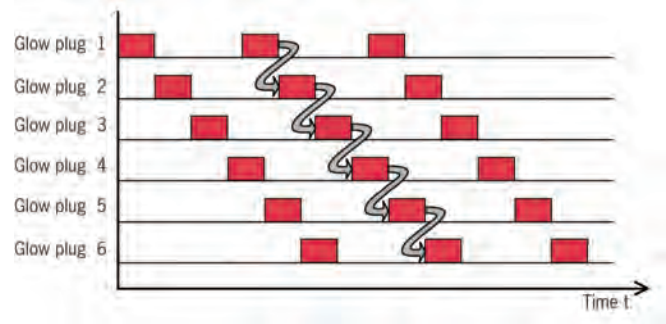
The post-heating function is interrupted if the engine speed increases or in the event of high load demands.

During pulse width modulated activation of the glow plugs in the post-heating phase, the control voltage is reduced to as low as 4.4V, depending on the operating conditions.



Notes:

Glow plug activation is delayed in order to relieve the load on the vehicle electrical supply voltage.



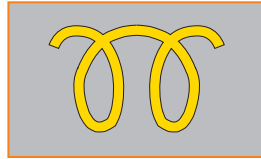
The falling signal edge always activates the next glow plug.

3. Interim heating

The glow plugs are activated by the DME control unit via the glow control unit during active regeneration of the diesel particulate filter. In addition to the heat required for the combustion sequence, this interim heating also generates additional heat in order to support regeneration of the diesel particulate filter. High temperatures are needed for diesel particulate filter regeneration in order to burn off the collected soot particles and therefore to clean the particle filter.

Glow Indicator Light

The glow indicator light is incorporated into the instrument cluster display.



- The glow indicator light lights up briefly when the ignition is switched on as a check function.
- If preheating is taking place, the lamp will stay lit up for longer, in line with the preheating time.
- The glow indicator light is not activated with the interim and post-heating functions.
- The glow indicator light flashes if a glow system malfunction is detected and in the event of engine control faults.

Glow Plugs

Each cylinder has one dedicated glow plug. The glow plugs are screwed vertically from above into a duct in the cylinder heads.



Each glow plug is positioned near an injector. The lower end of the glow plug, the heater coil, is located in close proximity to one of the injector nozzle outlet holes. During injection, the fuel spray is transported directly past the glow plug's protective tube, which the heater coil is located beneath. In this way the glow plugs do not only heat the aspirated fresh air but also the fuel emitted from the injectors. In addition to facilitating the required engine temperature, the heated fuel also promotes self-ignition of the fuel.

Ignition Delay

Explanation

With gasoline engines, combustion in the cylinder is triggered by an ignition spark. With a diesel engine, self-combustion of the fuel-air mixture should begin with the start of injection into the cylinder. In actual fact, there is a slight time delay between the start of injection and the start of combustion in the cylinder. This time period is called the ignition delay.

Dependencies

The lower the combustion chamber temperature and the fuel temperature are, the more poorly or later the air-fuel mixture ignites in a diesel engine, i.e. the longer the ignition delay is. The fuel quality rating (cetane number) also has an effect on the length of the ignition delay.

It is important to keep this ignition delay as short as possible. Late fuel self-ignition results in:

- Poor starting behaviour
- Loss of power
- Engine knocking
- Increased soot particle formation

The ignition delay is reduced by the glow system heating the fuel and the intake air.

The modern common rail injection system compensates for the different durations of ignition delay under various operating conditions by controlling the start of injection, based on electronic map control.

The most important parameters for controlling the start of injection are:

- Engine speed
- Load
- Fuel temperature
- Coolant temperature
- Cylinder pressure

The DME control unit compensates for the ignition delay by changing the start time of the injectors. The longer the ignition delay is, the earlier the DME control unit starts injection (start of activation) by the injectors.

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Cylinder Pressure-Based Combustion Control

Cylinder pressure-based combustion is another component used to achieve low emissions and at the same time achieve high fuel economy. The combustion chamber pressure sensor used in the 3.0 liter V6 TDI adds the combustion chamber pressure sensor function to a metal glow plug and is installed in Cylinder #2.

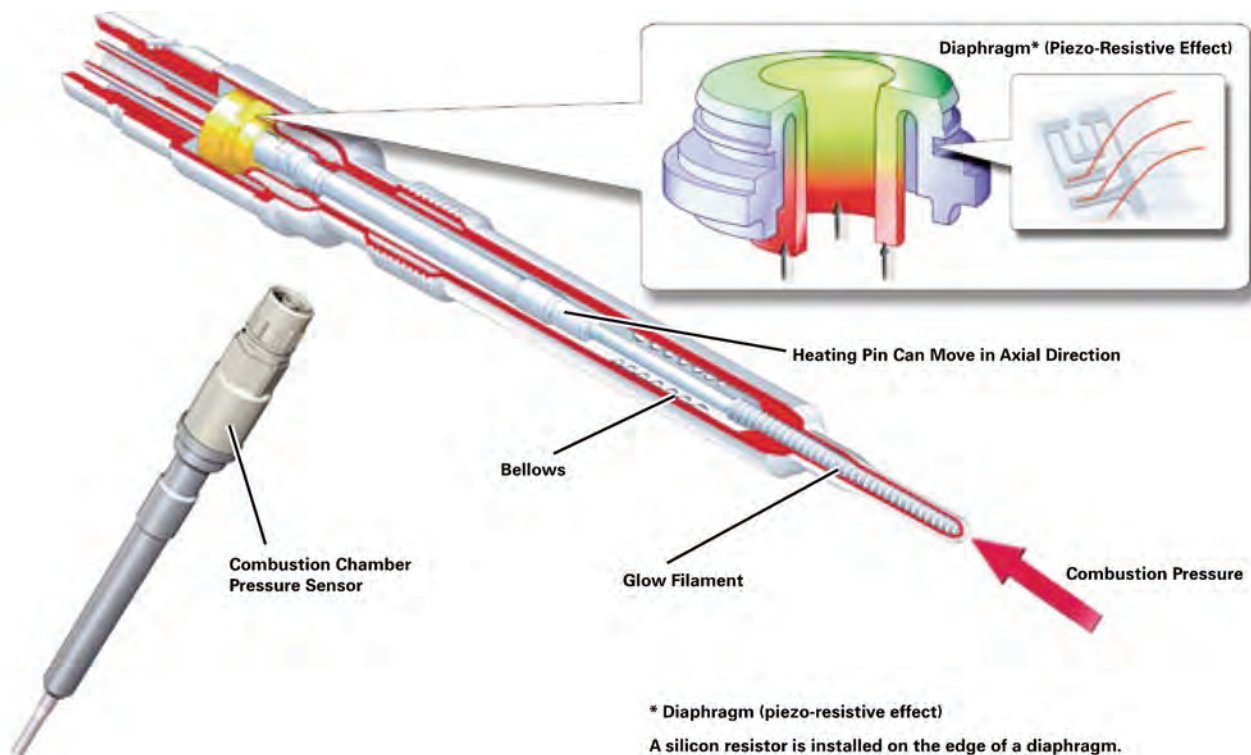
Cylinder pressure-based combustion permits the optimum adjustment of the injection point, and therefore the pressure profile during combustion, to different fuel qualities and exhaust gas recirculation rates. The course of combustion is determined from the pressure signal of the combustion chamber sensor and the engine speed signal.

Based on the deviation from the target/performance comparison, a correction value is determined with regard to the target combustion development, which causes an intervention in both the injection and the air system. The fuel quality, in particular the cetane rating, has a major effect on the course of combustion and the burn rate. With a low cetane rating, the ignition property of the fuel is reduced and thus the ignition delay is significantly increased. The point of 50% energy conversion moves in the "late" direction. This leads to incomplete or partial combustion.

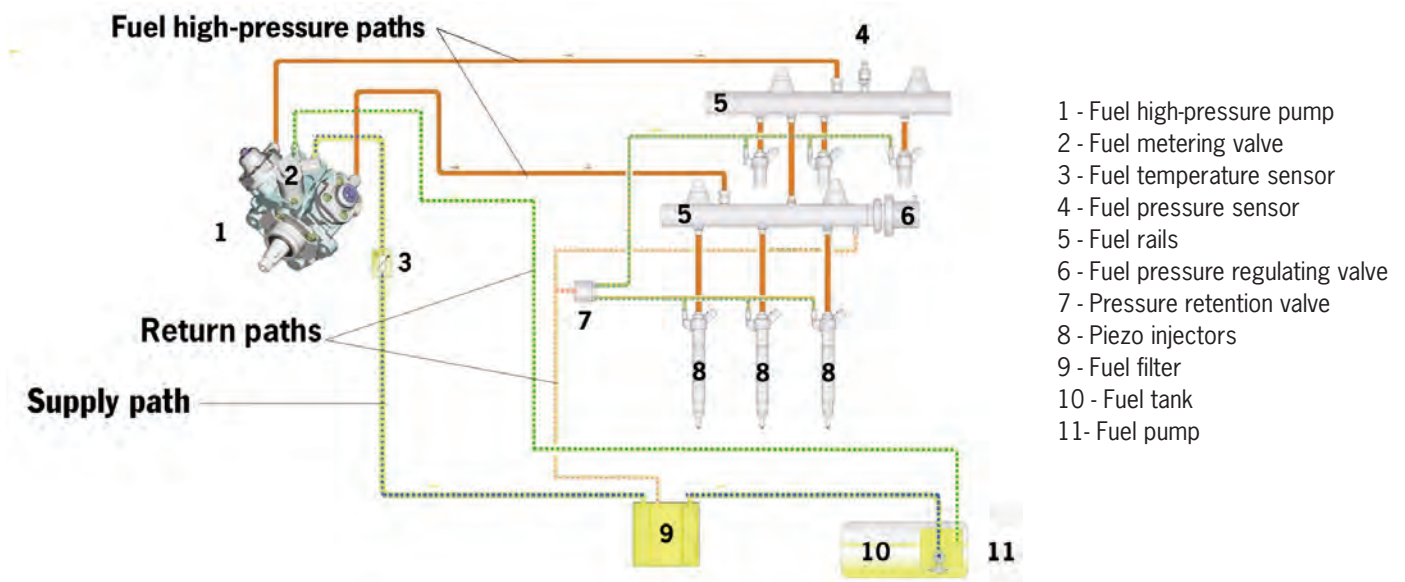
This provides the option of integrating this functionality in the existing space of the cylinder head. The heating pin is supported in such a way that it can move in an axial direction within the glow plug housing. It transmits the cylinder pressure to a diaphragm via a push rod. The deformation of the diaphragm is registered through the change in resistance and processed in an integrated electronic system. The processed voltage signal is transmitted to the engine control unit for further evaluation.

In engines without cylinder pressure-based control, combustion cannot be fully completed at very high EGR rates due to the high displacement towards late and retardation. This causes combustion conditions similar to misfiring. As a result, the HC and CO emissions rise drastically. The course of combustion is kept constant with the help of the cylinder pressure-based combustion control system and thus combustion is stabilized.

To counteract the higher ignition delay, the start of injection is moved to an earlier time. In this way the HC and CO emissions can be kept at a near constant low level with lower cetane ratings, low load, and higher EGR rates.



Fuel System



General Information

The fuel system of the 3.0 I V6 TDI engine is divided into the following areas:

- Low-pressure fuel supply (yellow)
- Fuel high-pressure system (red)
- Fuel return with 49 - 64 psi (3.4 - 4.4 bar) overpressure (orange)

With this engine, the common rail system with piezo injector technology is used as the fuel high-pressure system. The DFI technology was based on common rail systems. Therefore there are many similarities between direct injection gasoline engines and the common rail injection system. The most important feature of the common rail system is that the injection pressure can be generated independently of the engine speed and the injection volume.

The start of injection, which initiates combustion, can also be modulated independently of the operating condition of the running engine. Injection takes place at fuel pressures of between 3,770 psi (260 bar) and 29,000 psi (2,000 bar).

i Information!

If the wrong fuel has been put into the tank the ignition must not be switched on and the engine must not be started under any circumstances. The fuel tank must be emptied and cleaned. If the engine has been run with the wrong fuel, damage to the fuel high-pressure components can be expected. In this case, almost all the high-pressure area components will have to be replaced, the low-pressure system will need to be cleaned and the fuel filter must be replaced.

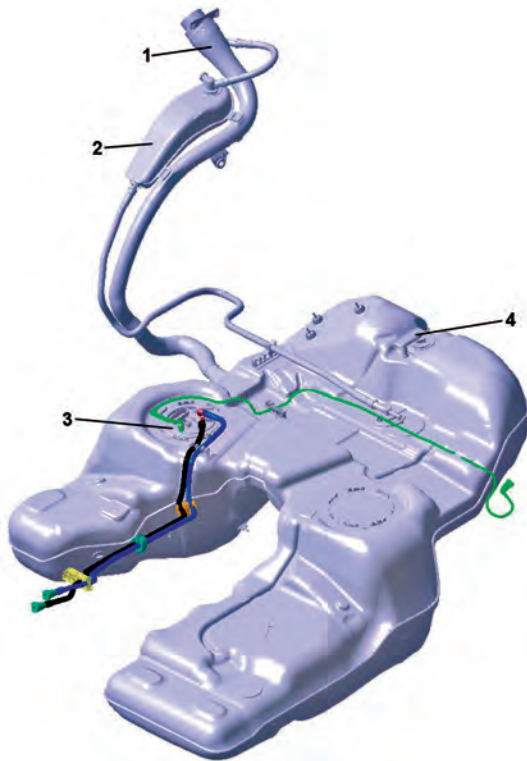
Notes:

Fuel, Exhaust & Engine Electrical

Low-Pressure Fuel Supply

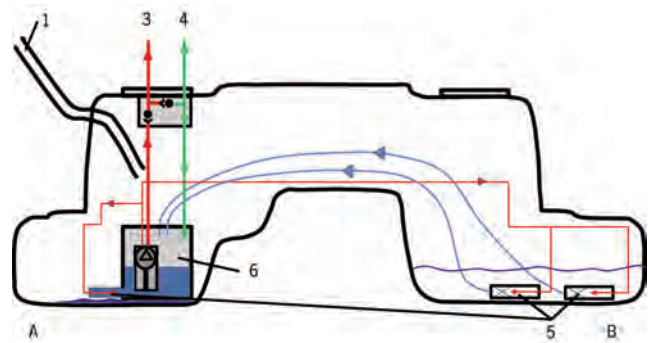
Fuel Tank

The fuel tank is divided up into a left-hand chamber and a right-hand chamber and is virtually identical to the fuel tank used in gasoline fueled Cayenne models.



- 1 Tank filler neck
- 2 Degassing tank
- 3 Electric fuel pump
- 4 Tank ventilation
- Engine compartment supply
- Return line

Some materials, for seals, pump chamber and pump flange, differ from those used in gasoline engines. The reason for this is the higher temperatures generated with diesel engines; the chemical load of the diesel fuel also has different characteristics when compared to gasoline.



- 1 Tank filler neck
- 3 Engine compartment supply
- 4 Return line
- 5 Sucking jet pump
- 6 Electric in-tank fuel pump with pump chamber
- A Right-hand chamber
- B Left-hand chamber

The internal structure is simpler and has fewer individual components relating to the fuel tank ventilation system when compared to gasoline type systems. This is due to the different behaviors of the fuels. The outgassing rate of gasoline is much higher than diesel, so tanks for gasoline need an additional active fuel tank ventilation system with carbon canister and tank leakage diagnosis that the diesel fuel tank does not need.

The actual fuel consumption is strongly influenced by:

- the driving style (moderate/sporty),
- the route (highway, country road, city),
- the operational conditions (e.g. road surface, ambient temperature, additional electrical loads switched on, roof rack fitted, full vehicle load).

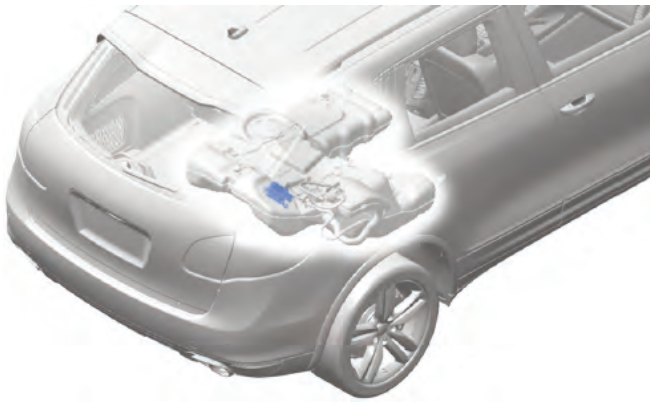
In-tank Fuel Pump

The in-tank fuel pump is located on the right-hand side of the fuel tank. It is operated as required as a function of engine load and engine speed via a separate control unit.



The in-tank fuel pump fulfils two tasks:

- It pumps the fuel from the fuel pump chamber to the fuel high-pressure pump in the engine compartment via the fuel filter
- It drives the sucking jet pumps.

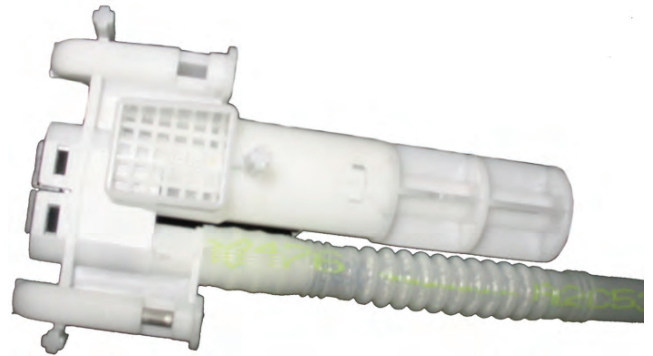


The fuel pump control unit is located on the top of the fuel tank.

It is a brushless three-phase pump. The engine speed request for the in-tank fuel pump is transmitted from the DME control unit to the control unit of the in-tank fuel pump via pulse width modulation. A predelivery pressure of approx. 50.75 psi (3.5 bar) is present at the high-pressure pump at idle speed.

The delivery pressure is adapted while the engine is running. If necessary, the in-tank fuel pump is briefly activated to build up pressure when opening the driver's door and/or when switching on the ignition to ensure the necessary fuel pressure to start the engine. The electric in-tank fuel pump is self-priming.

Sucking Jet Pumps



There are three sucking jet pumps in total in the fuel tank, which are operated via the electric in-tank fuel pump. There is a small sucking jet pump within the pump chamber of the electric in-tank fuel pump that pumps fuel from below into the pump chamber.

The sucking jet pumps installed in the tank opposite of the fuel pump ensure that the total volume of fuel on-board is available as a result of the "saddle tank" design. The sucking jet pumps are each connected to a propulsion jet line and a combined jet line. The sucking jet pumps work according to the Venturi principle, i.e. the electric in-tank fuel pump pumps fuel to the sucking jet pumps via the propulsion jet lines. The sucking jet entrains the fuel into the sucking jet pumps, which pump the sucking jet and the fuel taken in into the pump chamber of the electric in-tank fuel pump via the combined jet line. This enables the fuel chamber to always be kept full of fuel, regardless of the fuel level or longitudinal and lateral forces, to prevent air being taken in.

Notes:

Fuel, Exhaust & Engine Electrical

Tank Ventilation

Tank ventilation is necessary to prevent a vacuum within the fuel tank due to a drop in the fuel level while driving or differences in the temperature of the fuel. Vacuum would impair the fuel supply and cause deformation of the fuel tank. Air can get into the fuel tank from the outside via the tank ventilation line, but neither fuel nor air can escape via the ventilation system. There is a small filter installed at the outer end of the tank ventilation line to prevent the ingress of dirt into the fuel tank from the outside.

If the tank ventilation device fails, a spring-loaded vacuum valve in the tank cap opens to allow air into the fuel tank and in this way prevent damage to the fuel tank due to vacuum and insufficient fuel in the injection system while driving.

Fuel Level Sensor



The Cayenne Diesel has two fuel level sensors. There is one sensor on each side of the fuel tank for determining the fuel level. The signals from all the fuel level sensors are transmitted directly to the control unit for the instrument cluster via electric lines. The control unit adds up all the received values and compares the total with an electronically stored map. The resulting filling level is displayed in the instrument cluster.

The fuel level sensors on the Cayenne Diesel are designed as twin potentiometers (three-finger potentiometer, resistance sensor). The potentiometers are not encapsulated, i.e. they come into contact with the diesel fuel.

Fuel Filter

Parts of the high-pressure pump and the injectors are manufactured to an accuracy of 1/1,000 millimeter in some cases and therefore they react sensitively to the smallest amount of dirt. A problem that is virtually unknown in gasoline but which occurs frequently with diesel is water in the fuel.

The fuel filter protects the injection system from particles of dirt. The water is heavier than the diesel and it sinks to the lowest parts of the fuel system. In the advent of water contamination see the Workshop Manual. Another characteristic of diesel is gelling at low temperatures. At very low temperatures paraffin crystals could flocculate in the fuel. These paraffin crystals settle in the fuel filter and can block it.

To increase the fuel temperature and help prevent this, the fuel return line is routed to the fuel filter from:

- The fuel pressure-regulating valve
- The injectors into the fuel filter housing



- 1 - Supply line for fuel high-pressure pump
- 2 - Fuel filter
- 3 - Return line from regulating valve for fuel pressure and injectors
- 4 - Fuel supply line (from fuel tank)

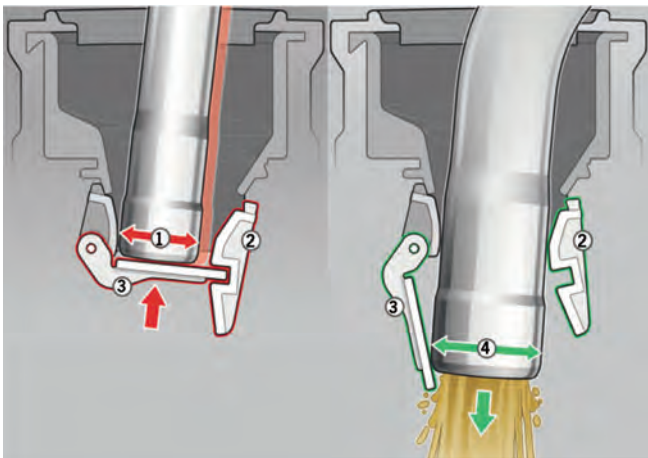
The fuel filter on the Cayenne Diesel is located on the right in the engine compartment. Depending on the market, the fuel filter may need to be replaced during intermediate servicing. Draining water from the fuel filter is necessary. In the event of water contamination-see workshop manual.

Fuel Return

The return line for the fuel high-pressure pump is routed directly back into the fuel tank (aids in heating fuel in the tank). The return line from the regulating valve for fuel pressure and injectors opens into the fuel filter housing.

Anti-Misfuelling System

Fuel nozzles for gasoline and diesel at fuel pumps have different spout diameters. The diameter of the diesel fuel nozzle is bigger than the gasoline fuel nozzle. A mechanical device prevents the flap in the tank filler neck from opening if an attempt is made to refuel the vehicle using the wrong fuel type.



Individual components of the anti-misfuelling system

- 1 - Spout for gasoline
- 2 - Pawl
- 3 - Tank filler neck flap
- 4 - Spout for diesel

Notes:

Anti-Misfuelling Device Closed (Gasoline fuel nozzle)

The spout diameter of the fuel nozzle for gasoline (1) is not wide enough for the spring-loaded pawl (2) to unlatch the flap in the tank filler neck (3). The flap prevents the fuel nozzle being inserted into the tank filler neck; misfuelling is not possible.

Anti-Misfuelling Device Open (Diesel fuel nozzle)

The larger spout diameter of the fuel nozzle for diesel (4) pushes the pawl (2) outwards and opens the spring-loaded flap in the tank filler neck (3). The flap is opened against spring force by inserting the spout. The vehicle can be refuelled.

Fuel Temperature Sensor

The fuel temperature sensor is located in the fuel supply line between the fuel filter and the high-pressure pump. It identifies the current fuel temperature and sends this information to the DME control unit. The fuel density can be derived from the fuel temperature.

The signal is used by the DME control unit as the correction value for calculating:

- The intake volume to the high-pressure pump
- The fuel pressure in the rails
- The injection volume
- The start of injection

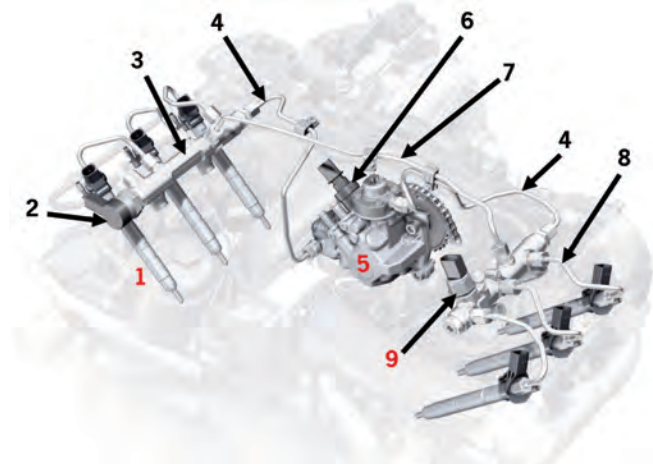
If the fuel temperature is too high the DME control unit reduces the injection volume in order to reduce the engine power. The high-pressure pump is therefore subject to less load and thus generates less heat; the fuel temperature decreases. In the event of a signal failure the DME control unit works with a fixed substitute value.

Fuel, Exhaust & Engine Electrical

Fuel High-Pressure System

The Bosch common rail system with piezo injectors is used as the high pressure injection system. The maximum rail pressure is 29,000 psi (2,000 bar). The rail pressure is generated by a two-plunger high-pressure pump. The high-pressure pump is located on the transmission side in the inner V of the cylinder block below the turbocharger.

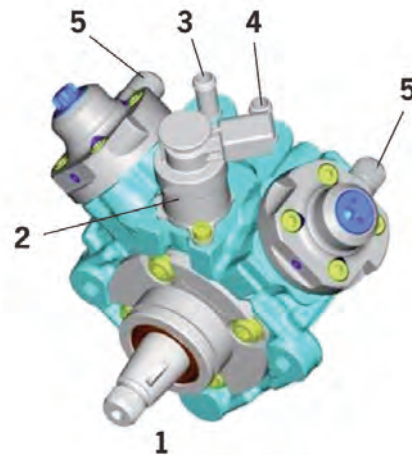
The pump is driven directly from the crankshaft by way of the drive chain for auxiliary drives. A ratio of 1:0.75 with respect to the crankshaft has been chosen to ensure that delivery is synchronous with fuel injection. Pump mounting on the engine is phase-orientated in order to minimize the chain forces. The fuel injection quantity differences between the individual cylinders, which are particularly important for low emissions, are extremely low over the whole map range. The piezo injectors are connected to the forged rails by very short stainless steel lines.



- 1 Piezo injector
- 2 Regulating valve for fuel pressure
- 3 Rails (pressure accumulator)
- 4 High-pressure lines for high pressure pump to rails
- 5 High-pressure pump
- 6 Fuel metering valve
- 7 High-pressure connecting line for rails
- 8 High-pressure connecting line for injectors
- 9 Fuel high-pressure sensor

Fuel High-Pressure Pump

The fuel high-pressure pump features a pump drive shaft driven directly from the crankshaft by way of the drive chain for auxiliary drives. A double cam is fixed to the drive shaft. The double cam is designed to move the pump plungers in the two high pressure pump cylinders, therefore ensuring that high pressure is generated. The highly pressurized diesel is then transported to the rails. In order to facilitate this, each high-pressure cylinder is connected to one rail by way of a dedicated line.



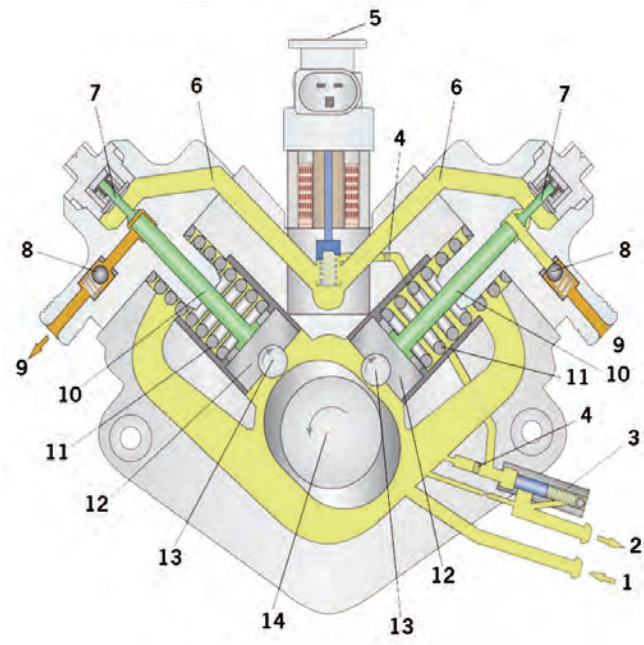
- 1 Drive shaft
- 2 Fuel metering valve
- 3 Fuel intake
- 4 Fuel return
- 5 Rail output

Overview of the High-Pressure Pump System

The fuel, subject to low pressure of approx. 72.5 psi (5 bar), reaches the high-pressure pump housing via the fuel intake.

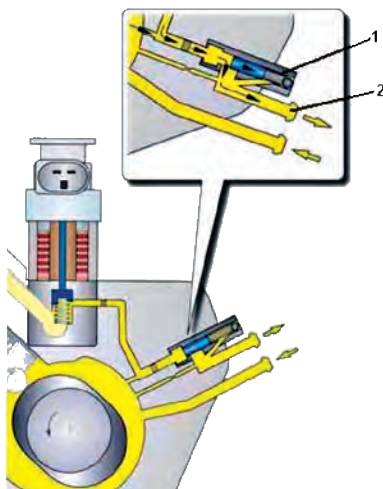
From there, the fuel flows to the inside of the fuel pump. Once inside of the pump the fuel:

- Cools the pump components
- Lubricates the moving parts



- 1 Fuel intake
- 2 Fuel return
- 3 Overflow valve
- 4 Fine filter
- 5 Fuel metering valve
- 6 Intake from the inside of the pump
- 7 Suction valve
- 8 Outlet and check valve
- 9 Rail output
- 10 Pump plunger
- 11 Plunger spring
- 12 Roller bearing
- 13 Idler pulley
- 14 Drive shaft with double cam

Overflow Valve



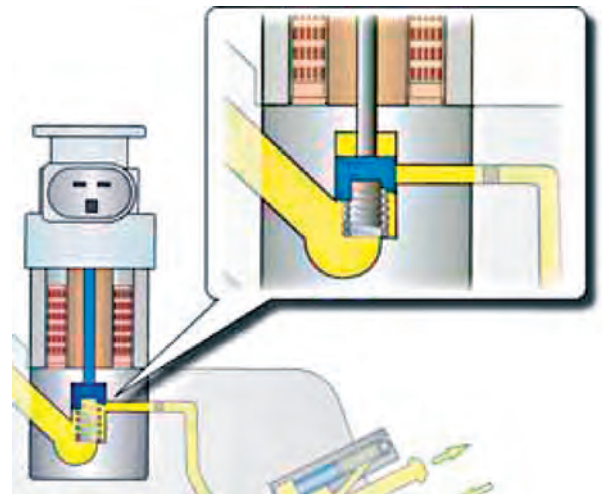
- 1 Overflow valve
- 2 Fuel return

The fuel in the low-pressure area of the high-pressure pump is controlled by the overflow valve. The electrically-driven fuel pump in the fuel tank transports the fuel from the fuel tank to the high-pressure pump at a pressure of approximately 72.5 psi (5 bar) therefore ensuring an adequate supply of fuel to the high-pressure pump under all operating conditions.

The 72.5 psi (5 bar) pressure of the incoming fuel is reduced to approx. 62.3 psi (4.3 bar) by the overflow valve. This ensures that the high-pressure pump is always supplied with more diesel than it feeds into the high-pressure area. The advantage of this is that the excess fuel supplied is used to cool the high-pressure pump components. The excess fuel is transported to the fuel tank via the fuel return connection.

Fuel Metering Valve

From the inside of the pump, the fuel flows to the fuel metering valve via a duct. The delivery rate of the high-pressure pump is determined by this valve. The fuel metering valve only allows the amount of fuel that is to be compressed into the two high-pressure cylinders.



This ensures that the pump only subjects as much fuel as is needed to high pressure. The high-pressure pump power loss is therefore reduced, especially in low load/engine speed ranges.

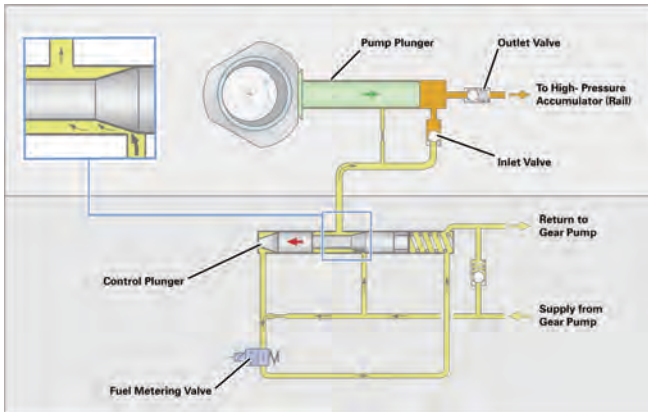
This results in two advantages:

- The fuel consumption is reduced
- The fuel temperature does not increase unnecessarily

Fuel, Exhaust & Engine Electrical

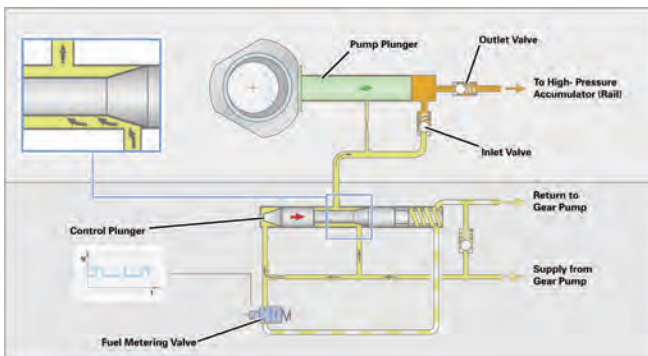
The valve is actuated by the DME control unit using pulse width modulation. When currentless, the valve is fully open; if this is the case, the fuel intake volume in the high-pressure chamber decreases. The longer the pulse width from the control unit is, the more the valve is closed and the fuel intake volume in the high-pressure chamber increases. If the valve is faulty, the DME control unit switches to limp-home mode and decreases the engine power.

Fuel Metering Valve Function – Without Current



When no current is supplied, the Fuel Metering Valve is open. The control plunger is shifted to the left by the spring force, and exposes the minimal cross-section (as illustrated) to the high-pressure pump. As a result of this, only a small quantity of fuel enters the high-pressure pump compression chamber.

Fuel Metering Valve Function – Initialized



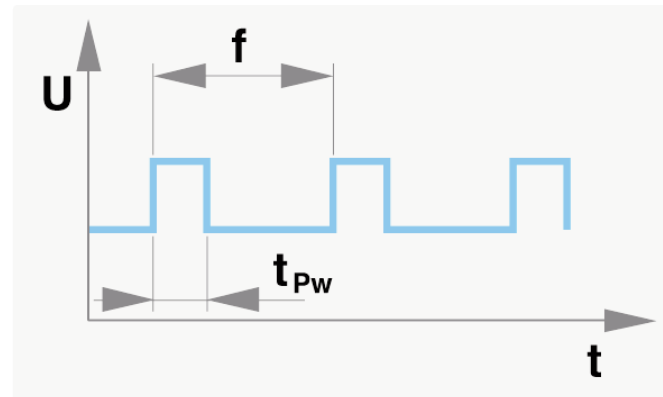
To increase the quantity inlet to the high-pressure pump, Fuel Metering Valve is controlled by the DME through a Pulse-Width-Modulated (PWM) signal. Due to the PWM signal, the Fuel Metering Valve is pulsed closed. This results in a control pressure, which acts on the control

plunger, downstream of the valve. Varying the on-off ratio changes the control pressure and therefore the position of the plunger. The control pressure decreases and the control plunger is shifted to the right as illustrated. This increases the fuel inlet to the high-pressure pump.

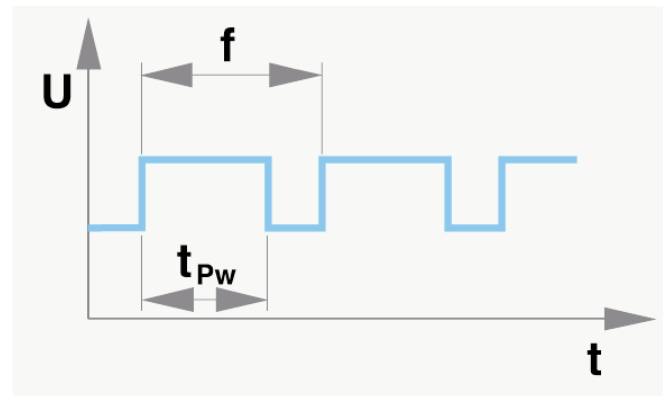
PWM Signals

PWM signals are “pulse-width-modulated” signals. These are square-wave signals with a variable on-time and constant frequency. Changing the valve on-time for fuel metering, for example, enables the control pressure and therefore the position of the control plunger to be changed.

Short Pulse Width = Small Fuel Inlet



Large Pulse Width = Large Fuel Inlet



U = Voltage

t = Time

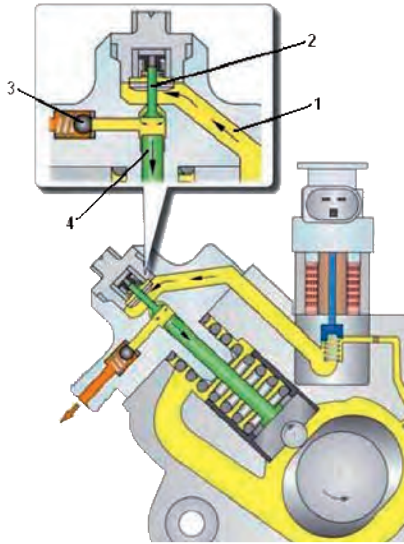
f = Cycle Duration (Frequency)

t_{PW} = Pulse Width (On-Time)

High-Pressure Area

From the fuel metering valve, the fuel reaches the high-pressure pump cylinder through an intake duct, via the suction valve. The pump plunger is moved by the double cam on the drive shaft. To minimize internal friction during power transmission, a roller and a roller bearing are installed between the pump plunger and the double cam.

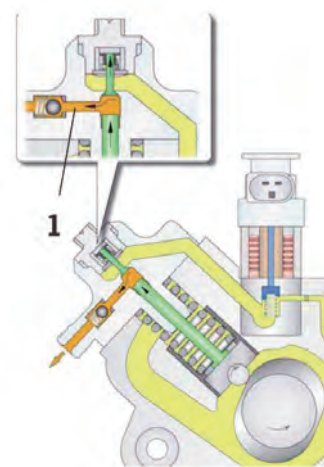
Intake Stroke



With a trailing cam, the pump plunger is forced downwards by the pressure of the plunger spring, thereby increasing the volume of the compression chamber. The pressure difference between the intake in the high-pressure pump and the combustion chamber causes the suction valve to open. The fuel flows into the compression chamber.

Notes:

Delivery Stroke



1 - Compression chamber

The drive shaft continues to be rotated by the drive chain and one of the double cams forces the pump plunger upwards via the idler pulley and the roller bearing. The upwards movement of the pump plunger causes the pressure in the compression chamber to rise and the suction valve closes. As soon as the fuel pressure in the compression chamber exceeds the pressure in the high-pressure area, the outlet valve/check valve opens and the fuel is transported through a line to the rail (high-pressure reservoir).

Fuel, Exhaust & Engine Electrical

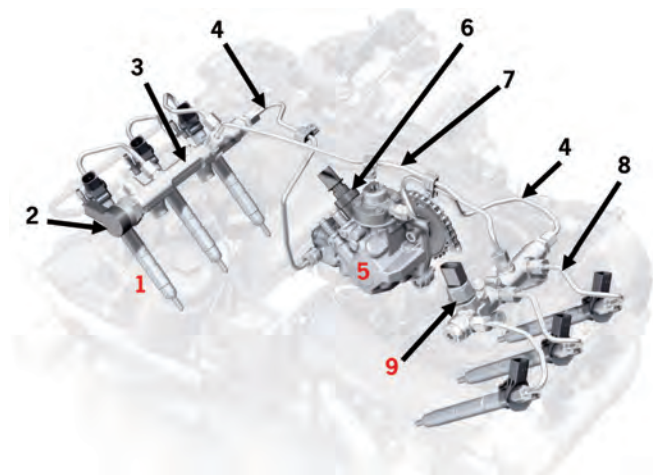
High-Pressure Reservoir

The fuel is transported into the rails through the feed lines coming from the high pressure units of the high-pressure pump. The rails are designed to store the pressure generated by the high-pressure pump and to transport it to the injectors.

Unintentional pressure fluctuations, caused by the high-pressure pump pulsating and by the opening and closing of the injectors, are compensated:

- By restrictors on the intakes of the rails
- By a shared connecting line between the two rails
- By the large storage volume of the rails
- And by the fuel pressure-regulating valve.

Three piezo high-pressure injectors are connected to each rail via metal lines. While the engine is running, the injectors are constantly subject to high-pressure irrespective of whether they are currently open or closed.



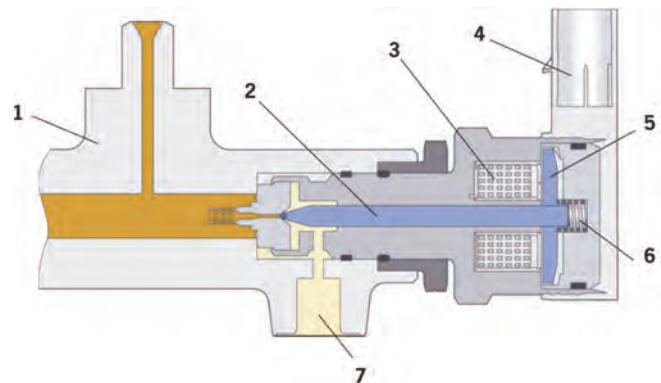
- 1 Piezo injector
- 2 Regulating valve for fuel pressure
- 3 Rails (pressure accumulator)
- 4 High-pressure lines for high pressure pump to rails
- 5 High-pressure pump
- 6 Fuel metering valve
- 7 High-pressure connecting line for rails
- 8 High-pressure connecting line for injectors
- 9 Fuel high-pressure sensor

High-Pressure Control

The common rail injection system is the only diesel injection system on the market that is able to adapt the injection pressure in line with the operating conditions, on an individual basis. To change the high pressure, the regulating valve (2) for fuel pressure is activated by the DME control unit using pulse width modulation. Excess fuel is transported to the fuel filter housing via the return line. The DME control unit receives feedback from the fuel high-pressure sensor (9) concerning the high pressure currently in the rails.

Fuel Pressure-regulating Valve

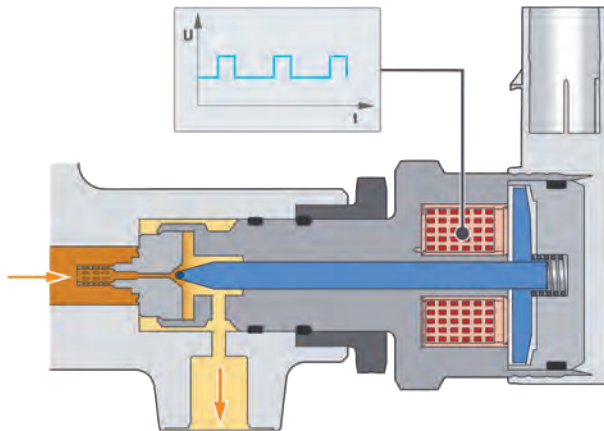
The fuel pressure-regulating valve is located at the end of the rail, bank 1. When currentless, the valve spring pushes the valve armature against its seat and thus ensures a fuel pre-delivery pressure of approximately 1,160 psi (80 bar) when the engine is switched off. This pressure is not sufficient to run the engine. A fuel pressure of approx. 1,740 psi (120 bar) is needed for engine start-up to be enabled.



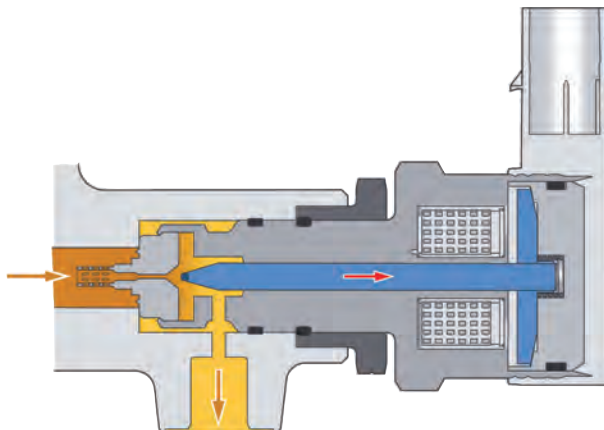
- 1 High-pressure reservoir (rail)
- 2 Needle valve
- 3 Solenoid coil
- 4 Electric connection
- 5 Valve armature
- 6 Valve spring
- 7 Connection for return line

Function/activation of the fuel pressure-regulating valve

As soon as the DME control unit receives information that the engine is on, it regulates the high pressure in the pressure accumulators via the fuel pressure valve. Depending on the operating condition, the operating pressure is between 3,770 and 29,000 psi (260 and 2,000 bar).



The larger the pulse/duty factor is with which the solenoid coil of the high-pressure adjuster is activated by the DME control unit, the more force is used to pull the valve armature towards the solenoid coil.



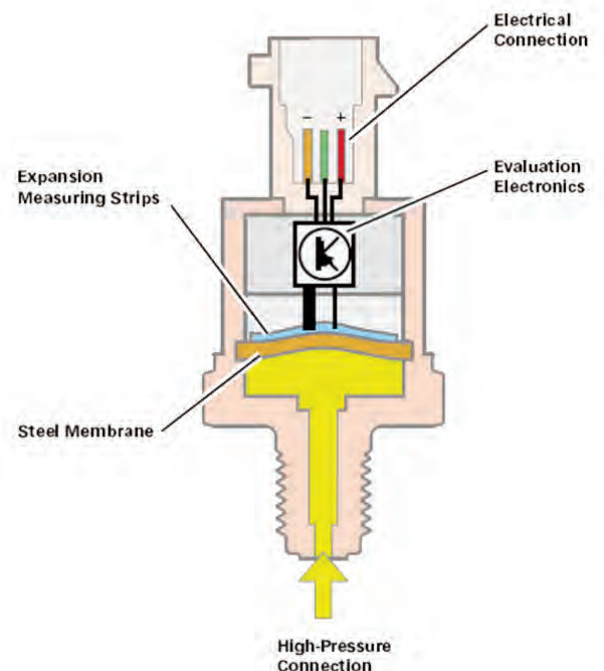
This also causes the pressure with which the needle valve against its seat to rise and the fuel pressure increases, as the changed activation causes the flow cross-section to the return line to change. Any pressure fluctuations can be compensated by means of regulating valve activation.

As soon as the control unit receives the “engine off” command it de-energizes the fuel pressure-regulating valve. The magnetic field in the solenoid coil collapses and the needle valve is then only forced against its seat by the valve spring. The fuel pressure in the rail reduces to approx. 1,160 psi (80 bar). The engine stops. If the sensor fails, it is no longer possible to start the engine.

Fuel Pressure Sensor

The fuel pressure sensor is located on the rail, bank 2, between the injector connecting lines for cylinder 4 and 5. The sensor has three electric connections, + and - as well as a signal line on which an analog signal is output during operation. When a change in fuel pressure occurs, the deflection of the steel diaphragm within the fuel pressure sensor also changes.

The resistance value of the strain gauge fixed to the steel diaphragm changes due to the different position, thus also changing the signal voltage sent to the DME control unit. If the fuel pressure sensor fails, the DME control unit works with a substitute value and the engine power is reduced.



Fuel, Exhaust & Engine Electrical

Interaction Between Fuel Metering Valve and Fuel Pressure Regulating Valve Regulation

With the common rail injection system, the fuel high-pressure is regulated by means of a dual regulator concept. Depending on the engine operating conditions, the fuel high pressure is adjusted either by the fuel pressure-regulating valve on the rail or via the fuel metering valve on the high-pressure pump.

Regulating by the Fuel Pressure Regulating valve on Fuel Rail

When

- The engine is started and
- To heat the fuel

the fuel high pressure is modulated by the fuel pressure-regulating valve. In order to heat the fuel quickly, more fuel is transported and compressed by the high-pressure pump than is needed. The resultant high return volume at the fuel pressure-regulating valve is sent back to the return line, from where it flows back to the fuel filter housing.

Regulating by the Fuel Metering Valve on High Pressure Pump

In the event of

- High injection volumes and
- High rail pressures

the fuel high pressure is controlled by the fuel metering valve. This facilitates demand-based regulation of the fuel high pressure.

The power consumption of the high-pressure pump is reduced in order to:

- Prevent the fuel being heated unnecessarily
- Reduce the power loss of the high-pressure pump
- Reduce fuel consumption

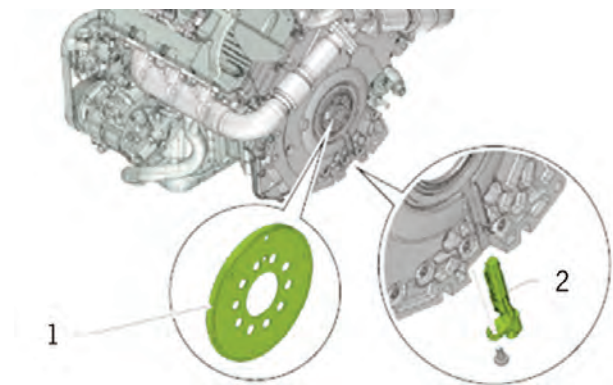
Regulating by Both Valves

- At idle speed
- During deceleration and
- With small injection volumes

the fuel pressure is regulated by both valves simultaneously. More precise regulation is thus achieved which improves idling quality, the emission values and the transition to deceleration.

Engine Speed Sensor

The inductive speed sensor is fixed to the rear engine cover and is used by the DME control unit to measure the primary values “engine speed” and “crankshaft position”. The sensor wheel is bolted to the end of the crank shaft in front of the flywheel. The DME control unit needs the engine speed and crankshaft position in order to calculate the injection timing and the injection volume. If the sensor is defective, the engine switches off and it can no longer be started.



- 1 Sensor wheel
2 Engine speed sensor

Fuel Temperature Sensor

The Fuel Temperature Sensor is located in the fuel supply pipe to the high-pressure pump it is used to determine the current fuel temperature.

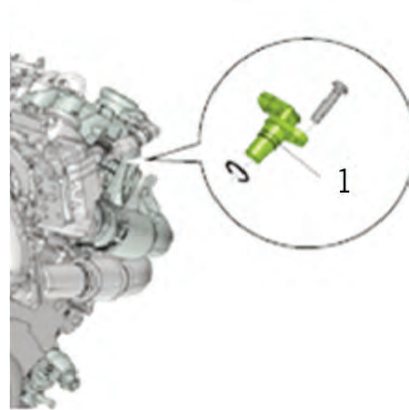


Signal Usage

The DME uses the Fuel Temperature Sensor signal to calculate the fuel density. This serves as a correction variable to calculate the injection quantity, to regulate the fuel pressure in the high-pressure accumulator, and to regulate the quantity inlet to the high-pressure pump. To protect the high-pressure pump against excessively high fuel temperatures, the Fuel Temperature Sensor is located in the fuel supply line to the high pressure pump. In the event of excessively high temperatures in the fuel supply system, the engine's output is limited in order to protect the high-pressure pump. As a result of this, the quantity of fuel to be compressed in the high-pressure pump is also indirectly reduced and the fuel temperature is lowered.

Notes:

Hall-effect Sensor



1 Hall-effect sensor

The Hall-effect sensor is mounted in the cylinder head cover of the cylinder head on bank 1. The sensor measures the position of the camshaft using the relevant sensor wheel and transmits the information to the DME control unit in the form of a square-wave signal. The signal is required to start the engine. The DME control unit uses the signal to identify the first cylinder and it detects smooth engine running in conjunction with the engine speed sensor signal. In the event of failure it is no longer possible to start the engine.

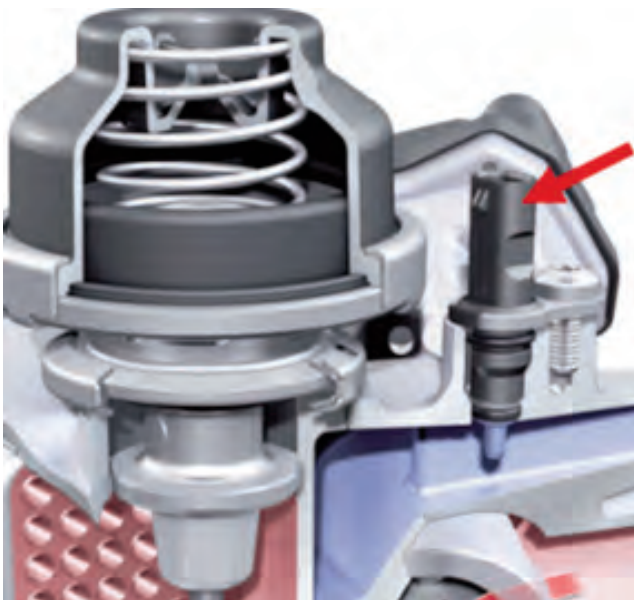
Fuel, Exhaust & Engine Electrical

Pedal Sensor



The pedal sensor with integrated twin potentiometer provides the primary load value for the DME control unit. The DME control unit uses the signal to calculate the injection volume and the start of injection. The kickdown switch function is integrated in the unit. If one sensor fails, the engine is run with significantly decreased power and the engine speed only increases slowly. If both potentiometers fail the DME control unit no longer reacts to changes to the accelerator pedal position and the engine runs at increased idle speed.

Coolant Temperature Sensor (NTC 2)



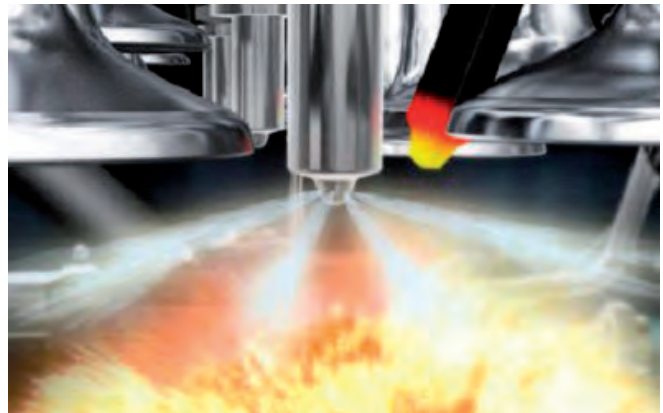
The NTC 2 is located in the top of the EGR console; it reports the coolant temperature to the DME control unit.

The signal is used by the DME control unit as the primary value for activating the glow plugs via the glow control unit and as the correction value for calculating:

- The start of injection
- The injection volume
- The boost pressure
- The exhaust gas recirculation volume

On the basis of the coolant temperature, the glow control unit determines whether and how long preheating should take place for. If the sensor is defective the DME control unit uses the signal from the coolant temperature sensor at the radiator outlet and a fixed substitute value. Other important sensors used by the DME control unit for regulating the injection system will be described later in this manual.

Injector Technology



Inline injectors with piezo technology are installed in the 3.0 I V6 TDI engines. They have multiple nozzle bores. The fuel sprays sideways out of the nozzle holder, at a downwards angle. In combination with the piston crown recess, this creates optimum swirl in order to mix fuel and air as well as possible and therefore to facilitate optimum combustion.

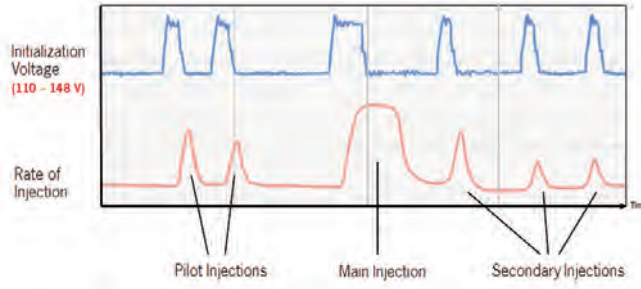
The special features of these injectors are:

- Small installation dimensions
- Less moved mass
- Very short switching times
- Multiple injections are possible per working cycle
- Finely meterable fuel injection volumes

With the diesel engine

- Up to two pre-injections and
- Up to three post-injections

are carried out in addition to the main injection under certain operating conditions.



Pre-Injection

Pre-injections (sometimes referred to as pilot injections) are carried out depending on the operating condition and can be varied in terms of number, timing and injection volume. However, they always involve very small injection volumes. The pre-injection phases are designed to prepare for main injection.

With a cold engine and at low engine speeds, two pre-injections are carried out in order to prevent loud engine noise which can result from the increased ignition delay when the engine is cold. (See Glow system, Ignition delay section)

The pre-injections

- Pre-heat the combustion chamber
- Increase the air movement in the combustion chamber.

This causes

- A short main injection ignition delay
- A steady pressure increase in the cylinder
- Low NO_x emissions

resulting in the following advantages:

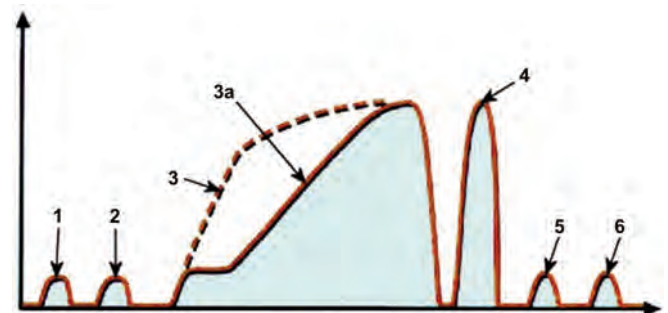
- Smoother, quieter engine operation, especially at idle speed
- Improved exhaust gas emissions

As the load and the engine speed increase, only a single pre-injection is carried out in order to keep the NO_x emissions at a low level. NO_x is produced depending on the temperature and the pressure. The higher the combustion

temperatures are, the higher the nitrogen oxide emissions will be. Pre-injection only makes a minor contribution to the increase in torque. Therefore pre-injection is completely deactivated at full throttle and at high engine speeds. The injection pressure and the injection volume required for the main injection must be attained quickly in order to achieve the efficiency required.

Main Injection

After pre-injection there is a short break before main injection (3) takes place. Combustion, taking place straight after main injection, helps to produce engine torque. The amount of injection pressure of the main injection increases in the shape of a ramp (3a) at low load and engine speed. At high load and engine speed the injection pressure of the main injection (3) increases very quickly. The highest pressure of 29,000 psi (2,000 bar) is achieved at high load and engine speed.



- 1 Pre-injection
- 2 Pre-injection
- 3 Main injection at high load/engine speed
- 3a Main injection at low load/engine speed
- 4 1 post-injection
- 5 2 post-injection
- 6 3 post-injection

Post Injection

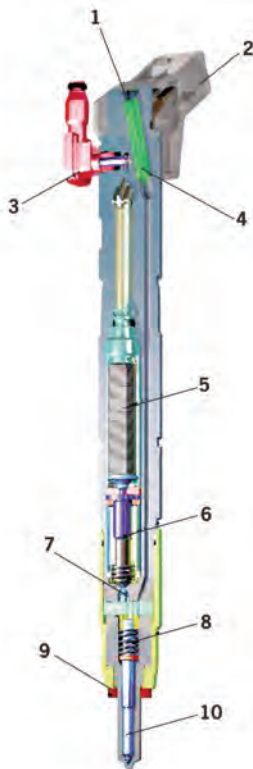
The first post-injection (4) assists fast heating of the oxidation catalytic converter and the diesel particulate filter when the engine is cold. The second post-injection (5) is used to help maintain/increase exhaust gas temperatures and for active regeneration of the diesel particulate filter. The third post-injection is used for regeneration of the diesel particulate filter only, and takes place so late that the fuel reaches the oxidation catalytic converter in gaseous state. The fuel only combusts in the converter (catalytic converter burner) and therefore produces the exhaust gas temperatures needed for regeneration of the diesel particulate filter.

Fuel, Exhaust & Engine Electrical

Piezo Injector

As opposed to the gasoline engine, the injector needle of electrically activated diesel injectors is opened hydraulically, by creating a pressure difference. The hydraulic control valve, which produces the change in pressure for opening and closing the injector, is activated via an electric piezo actuator. The inverse piezo-electric effect is applied to control the piezo actuator.

The piezo technology is used as it makes it possible to switch the injector significantly more quickly than would be possible with a conventional solenoid valve (approximately four times faster). The piezo actuator switches in less than one ten-thousandth of a second.



- 1 Fuel intake (high pressure)
- 2 Electric connection
- 3 Fuel return
- 4 Edge filter
- 5 Piezo module
- 6 Coupler module
- 7 Switching valve
- 8 Nozzle spring
- 9 Copper sealing ring
- 10 Injector needle

In comparison with solenoid valve-controlled injectors, piezo technology has approximately 75% less moving mass at the injector needle.

This results in the following advantages:

- Very short switching times
- Multiple injections per working cycle are possible
- Precise injection quantities

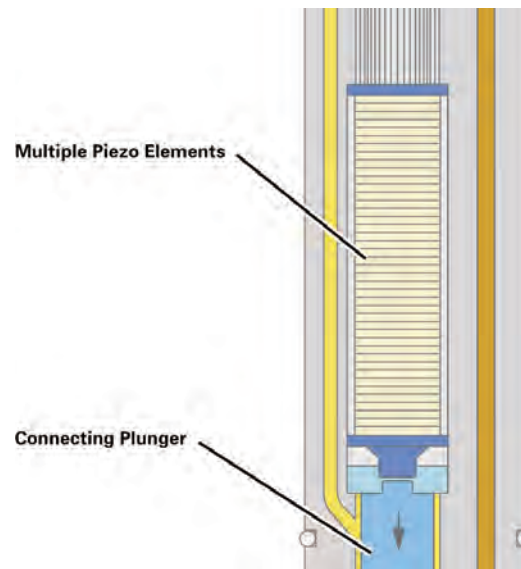
Piezo Effect

“Piezo” is a Greek word meaning “pressure.” Piezo elements are frequently used in sensor systems. Pressure applied to a piezo element produces a measurable voltage. This behavior on the part of a crystalline structure is called the piezoelectric effect.

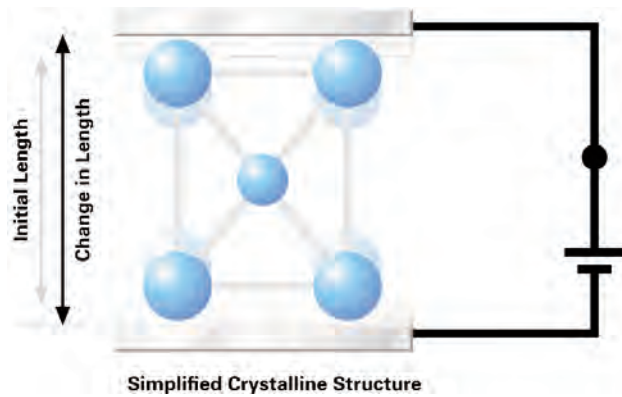
Inverse Piezo-Electric Effect

The piezo-electric effect is employed in reverse form in a piezo-controlled actuator. When a voltage is applied to the piezo element the crystalline structure reacts by changing length either by expanding or contracting depending on the polarity.

Piezo Actuator

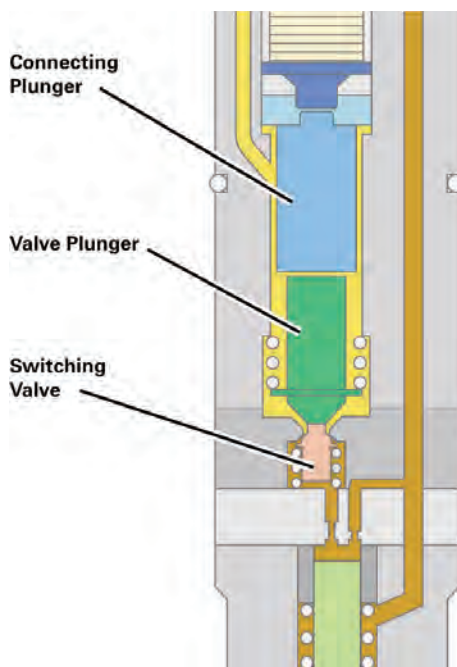


The piezo actuator is comprised of many piezo elements connected to each other electrically, so that switching travel is sufficient to control the fuel injector. With the application of a voltage, between 110 to 148 volts, the piezo actuator expands by up to 0.0012 inch (0.03 mm). For comparison purposes, a human hair has a diameter of approximately 0.0024 inch (0.06 mm).



Piezo Element with Voltage V Applied

Connecting Module



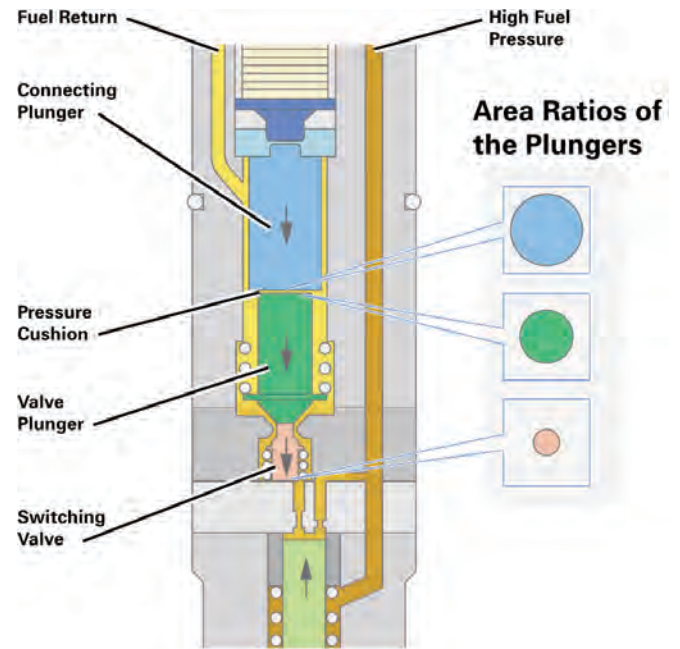
Connecting Module in Resting Position

The connecting module is comprised of the connecting plunger and the valve plunger. The connecting module acts in the same manner as a hydraulic cylinder. It hydraulically converts the piezo actuator's very rapid longitudinal change and actuates the switching valve. Due to hydraulic force transmission, switching valve opening is dampened, and injection is therefore precisely controlled.

Advantages of hydraulic force transmission:

- Low friction forces
- Damping of moving components
- Compensation of component longitudinal changes caused by thermal expansion
- No mechanical forces acting on the fuel injector needles

Hydraulic Principle



Connecting Module Actuated

The connecting module is a hydraulic system in which both the forces and the plunger areas behave in relation to each other. In the connecting module, the area of the connecting plunger is greater than the area of the valve plunger. The valve plunger is therefore actuated by the connecting plunger's force.

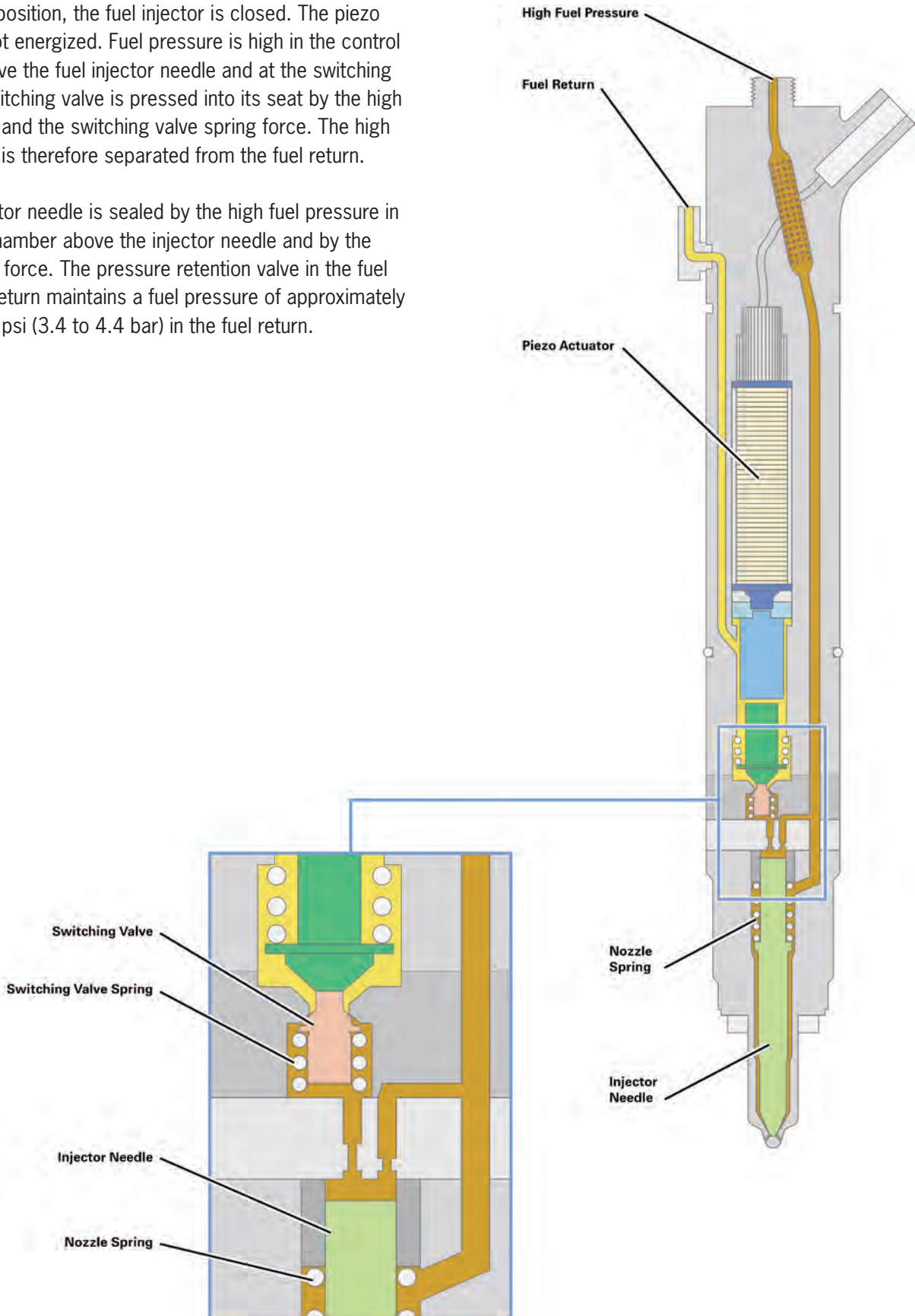
The area ratio of the connecting plunger to the switching valve is several times higher extending its applied travel. As a result, the switching valve can be actuated by the connecting module counter to the rail pressure. The pressure retention valve in the fuel return maintains a fuel pressure of approximately 49.3 to 63.8 psi (3.4 to 4.4 bar) in the connecting module. This fuel pressure serves as a pressure cushion for hydraulic force transmission between the connecting plunger and valve plunger.

Fuel, Exhaust & Engine Electrical

Fuel Injector in Resting Position

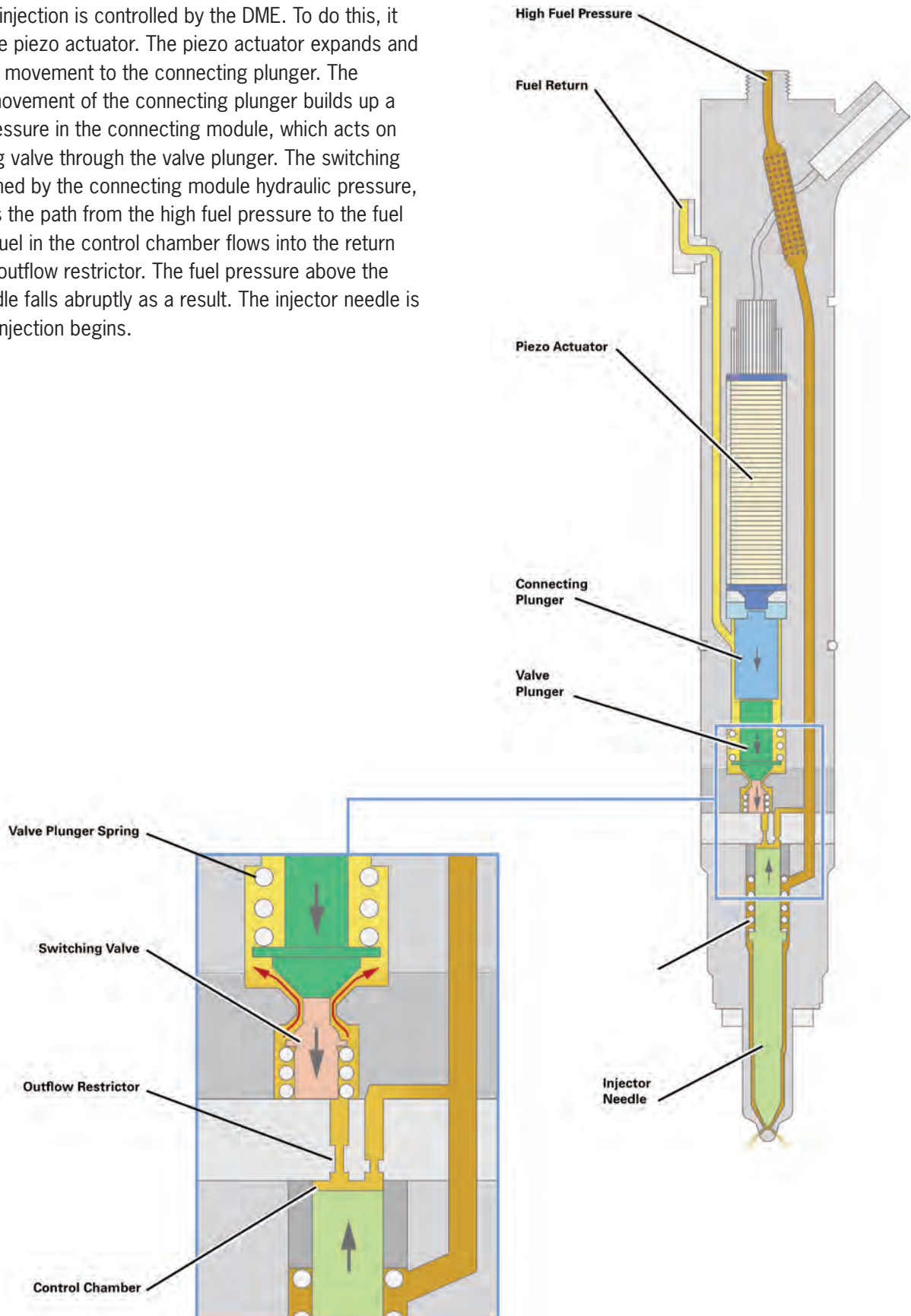
In its resting position, the fuel injector is closed. The piezo actuator is not energized. Fuel pressure is high in the control chamber above the fuel injector needle and at the switching valve. The switching valve is pressed into its seat by the high fuel pressure and the switching valve spring force. The high fuel pressure is therefore separated from the fuel return.

The fuel injector needle is sealed by the high fuel pressure in the control chamber above the injector needle and by the nozzle spring force. The pressure retention valve in the fuel injector fuel return maintains a fuel pressure of approximately 49.3 to 63.8 psi (3.4 to 4.4 bar) in the fuel return.



Start of Injection

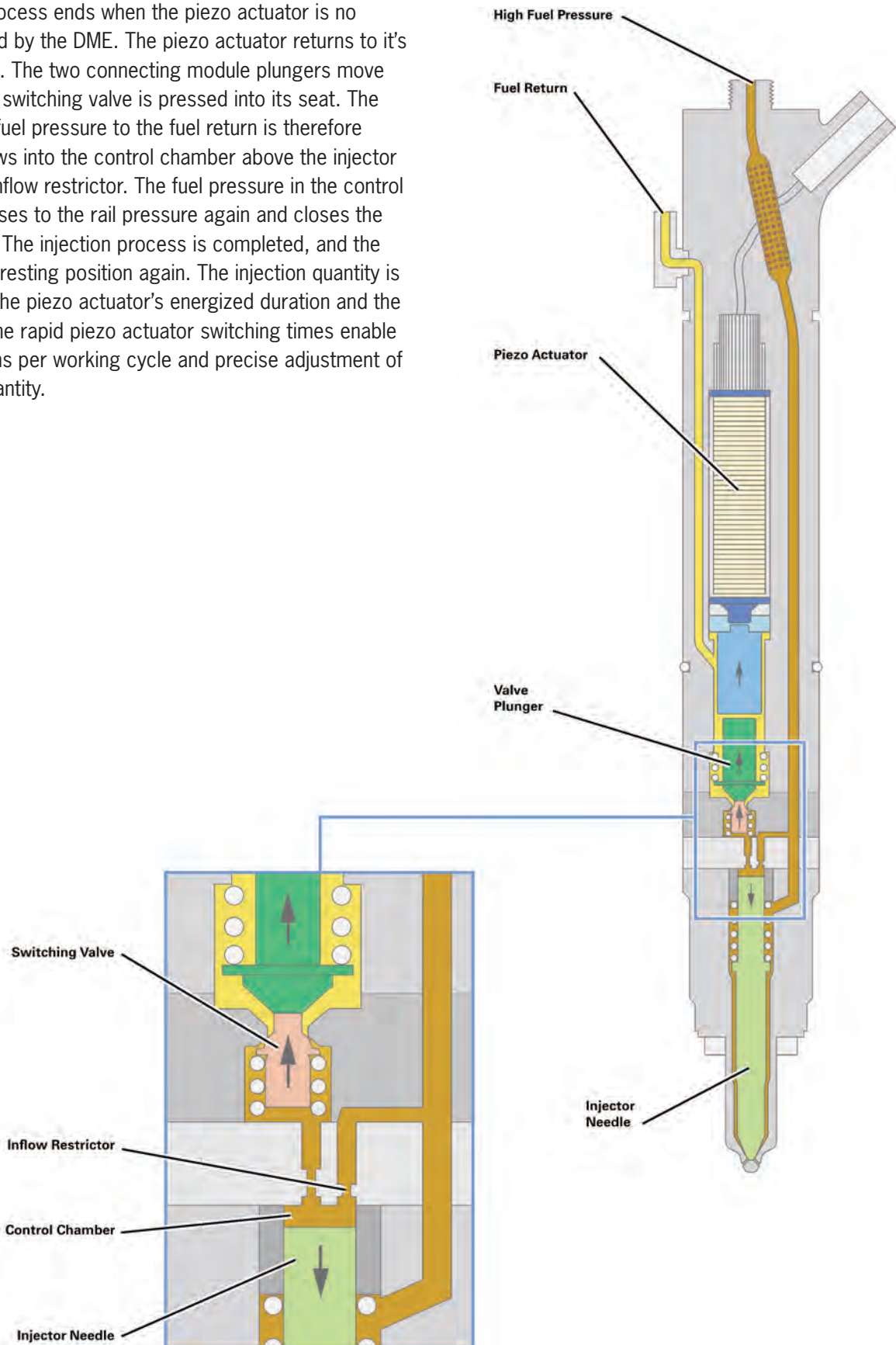
The start of injection is controlled by the DME. To do this, it energizes the piezo actuator. The piezo actuator expands and transfers its movement to the connecting plunger. The downward movement of the connecting plunger builds up a hydraulic pressure in the connecting module, which acts on the switching valve through the valve plunger. The switching valve is opened by the connecting module hydraulic pressure, and releases the path from the high fuel pressure to the fuel return. The fuel in the control chamber flows into the return through the outflow restrictor. The fuel pressure above the injector needle falls abruptly as a result. The injector needle is raised, and injection begins.



Fuel, Exhaust & Engine Electrical

End of Injection

The injection process ends when the piezo actuator is no longer energized by the DME. The piezo actuator returns to its original position. The two connecting module plungers move upward and the switching valve is pressed into its seat. The path from high fuel pressure to the fuel return is therefore sealed. Fuel flows into the control chamber above the injector needle via the inflow restrictor. The fuel pressure in the control chamber increases to the rail pressure again and closes the injector needle. The injection process is completed, and the injector is in its resting position again. The injection quantity is determined by the piezo actuator's energized duration and the rail pressure. The rapid piezo actuator switching times enable several injections per working cycle and precise adjustment of the injection quantity.



Injector Tolerance Compensation

For diesel engines and with respect to

- Fuel consumption,
- Exhaust gas emissions
- Smooth running
- Performance

it is essential that the injectors work extremely precisely to ensure accurate start of injection and a precise delivery rate.

Therefore

- While the engine is running, the smooth running control compensates for wear and soiling-induced deviations by changing the injector timings
- Injector production tolerances are taken into account and compensated by injector quantity adjustment



Important!

After an injector has been replaced, the DME control unit must be informed of the relevant code via the PIWIS Tester so that the control unit adapts in line with the characteristics of the injector and activates it accordingly.

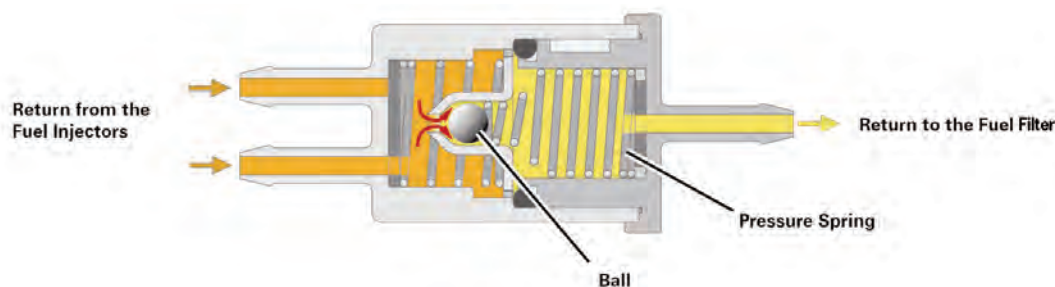
Injector Quantity Adjustment



Even very small tolerances during the production of an injector cause differences in the responsiveness of the injectors. Therefore the characteristics of each injector after production or after repair are measured in various different operating conditions by way of a special test stand. The injector characteristics measured in this way are recorded in a tolerance code. This 7-position IMA code, which can consist of both numbers and letters, is recorded on the injector.

Pressure Control Valve

This component is a mechanical valve. The pressure control valve is connected in line between the two injector return lines and the fuel return line to the fuel filter housing. It ensures a constant backpressure of 49.3 to 63.8 psi (3.4 to 4.4 bar) in the return lines coming from the injectors during engine operation only. This admission pressure is required to ensure that the injectors function correctly.



Notes:

Fuel, Exhaust & Engine Electrical

Intake System

The intake system in the 3.0 I V6 TDI engine is equipped with:

- A hot-film mass air flow sensor (HFM-5)
- A VTG turbocharger
- Two charge-air coolers
- A boost pressure and air temperature sensor (NTC1)
- A throttle valve control unit
- Two-part intake manifolds with swirl flap control

Air Filter

The engine features an air filter which is installed in the air filter housing to the right of the engine in the direction of travel.

Mass Air Flow Sensor



The hot-film mass air flow sensor HFM-5 detects the actually aspirated air mass and relays this value to the DME control unit as an analog signal.

The DME control unit analyses the signal for the following functions:

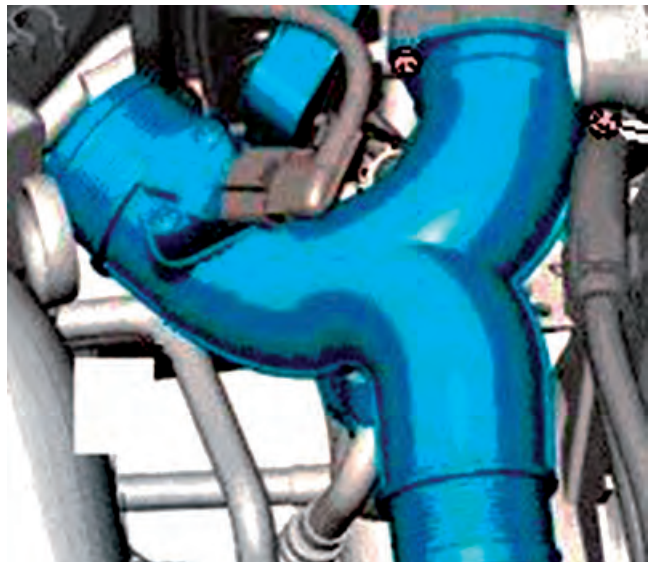
- Full throttle injection volume limiting
- Calculating the EGR rate
- Determining the load condition of the diesel particulate filter

If the signal fails, the DME control unit uses a substitute value, calculated from the boost pressure and engine speed signal. The engine power is reduced and OBD indicator light activation is delayed.

Charge-air Cooler

The two charge-air coolers, connected in parallel, are located at the front of the engine and they are designed to remove the heat generated by the temperature of the VTG turbocharger, as well as that generated by the compression, from the fresh air. By reducing the air temperature, the fresh air mass and therefore the density of the air is increased and fresh air filling in the cylinder increases. The charge-air cooling provides the 3.0 I V6 TDI engine with additional torque and power.

Boost Pressure and Air Temperature Sensor (NTC1)

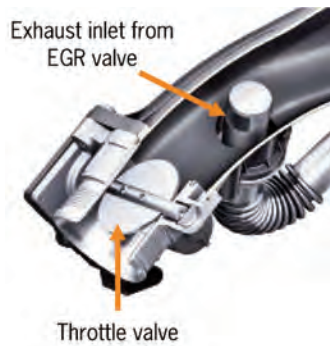


The boost pressure and air temperature sensors are integrated into a shared housing. The joint component is screwed into the shared connecting flange which connects the hoses of the charge-air cooler with the throttle valve control unit.

The DME control unit uses the sensor signals for:

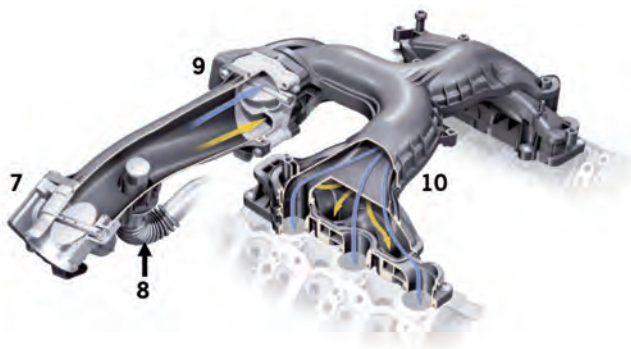
- Boost-pressure control
- Injection volume calculation
- Exhaust gas recirculation

Throttle Valve Control Unit



The throttle valve control unit is made up of a mechanical throttle valve and an electric unit consisting of a servo motor and potentiometers. If, when the engine is running, the throttle valve is not switched on for EGR control or for regenerating the diesel particulate filter, it is fully open while the engine is running.

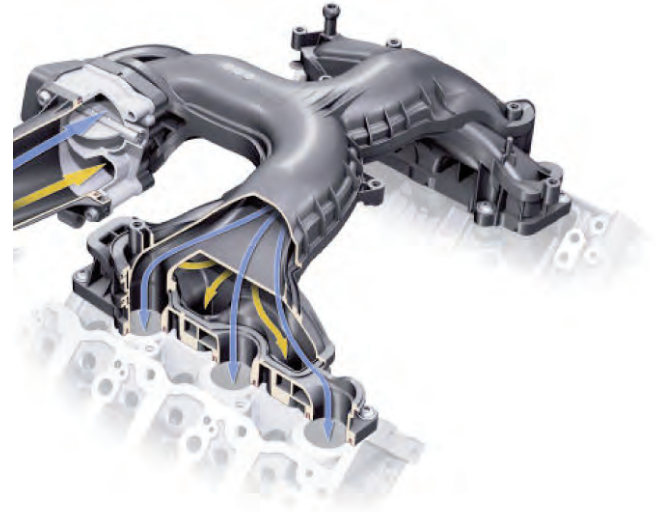
Overview of the Intake-air Distributor System



- | | |
|------------------------------------|-----------------------------|
| 7 Throttle module (shut-off valve) | 8 Exhaust gas supply |
| 9 Swirl flap module | 10 Two-part intake manifold |

After the throttle module (7), the recirculated exhaust gas is fed into the intake tract; this takes place by way of a thermally isolated metal construction made of stainless steel (8) in such a manner as to achieve favorable flow characteristics. Activating the throttle valve (7) at low rpm increases the air speed at the exhaust inlet (8) and ensures optimum mixture of cooled fresh air and the recirculated exhaust gases. This is important for proper combustion of the fuel in the cylinders even when the operating conditions are unfavorable (low air speed, high exhaust gas recirculation rate). The NO_x and soot content decreases.

Thanks to the geometric design for exhaust gas infeed (8), wall deposits on the inner wall of the plastic tube are avoided in all operating points and good mixture characteristics are ensured at the same time. The throttle valve (7) is also activated for regeneration purposes and to improve the engine's switch-off behavior.



Swirl flap control is performed by one swirl flap motor.

The swirl flap can be continuously adjusted by the DME control unit, depending on:

- Engine speed and
- Load.

As the load and the engine speed increase, the flap opens wider in order to feed more air into the engine. By changing the swirl flap angle, the angular momentum of the aspirated air also changes in order to attain an optimum air-fuel mixture under all operating conditions.

Two-part Intake Manifold

Downstream of the central swirl flap (9), the intake manifold (10) is in two parts as far as the two cylinder banks. The upper half routes the air into the filling ports and the lower half routes the air into the swirl ports. The plastic intake manifold (10) comprises three shells that are friction-welded together. The intake manifold geometry has been designed with respect to pressure loss and allows for equal distribution of the air flows to the individual cylinders.

Fuel, Exhaust & Engine Electrical

Turbocharging



Turbocharging supplies the engine with a larger air mass.

A larger air mass

- Reduces the exhaust emissions at full throttle, with the injection volume staying the same
- Increases engine power when the injection volume is increased

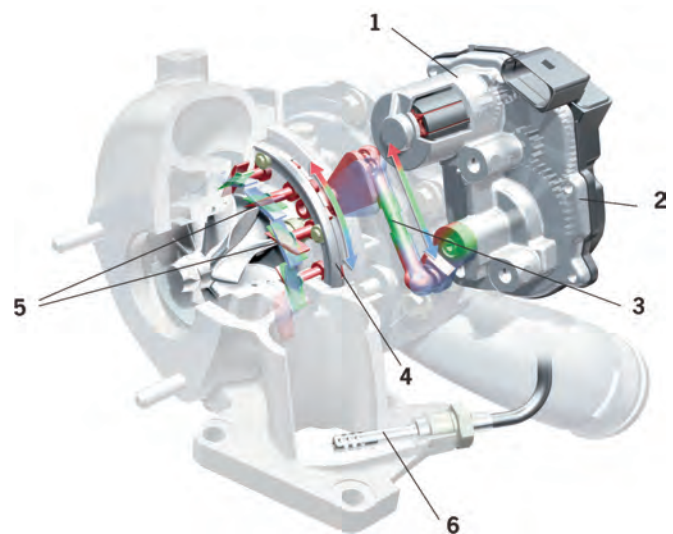
With a turbocharger, the exhaust gases are transported via an exhaust turbine. The exhaust turbine rotates due to the exhaust gas flow, thereby driving a compressor wheel which is connected to the exhaust turbine wheel via a shared shaft. The compressor wheel is installed in the intake area, ahead of the charge-air coolers and, by rotating, it compresses the aspirated fresh air in order to increase the air mass flowing into the cylinder and therefore to increase the air density. Large turbochargers have poor responsiveness (large “turbo lag”) due to the high acceleration mass of the turbine wheel and the low flow momentum of the exhaust gas.

In contrast to small turbochargers, the exhaust back pressures are lower at high air flow rates due to the larger flow cross-sections in the turbine housing and turbine wheel. A higher maximum engine power is thereby achieved. The Garret VTG turbocharger was developed to deal with “turbo lag”. A VTG turbocharger, which allows for boost pressures of up to 26 psi/1.8 bar (relative), is installed in the 3.0 I V6 TDI engine.

As well as using an air gap-insulated exhaust manifold, the exhaust turbine housing of the VTG turbocharger has also been enclosed with a heat-insulating aluminum foil (integral insulation) in order to reduce the heat emitted by the exhaust gases into the engine compartment and to effectively transfer the exhaust-gas temperature to the oxidation catalytic converter and the diesel particle filter. The operating temperature of the catalytic converter and the necessary ignition temperature for the soot particles deposited in the diesel particle filter are reached more quickly and emissions are reduced. The engine oil lubrication supply and return line at the turbocharger are now integrated in the mount pedestal and therefore in the turbocharger housing.

VTG Turbocharger

The VTG turbocharger is a turbocharger with variable turbine geometry. On the exhaust side, it is installed between the connecting piece which connects the exhaust manifolds for both banks and the oxidation catalytic converter, and, on the fresh air side, it is located between the mass air flow sensor and the charge-air cooler connections. The component can be found in the vehicle on the top of the engine, towards the plenum panel.



- 1 Servo motor
- 2 Control unit with potentiometer
- 3 Coupling rod
- 4 Adjusting ring
- 5 Guide blades
- 6 Exhaust gas temperature sensor

Variable turbine geometry means that the DME control unit can use the turbocharger control unit to activate an electric stepper motor, which is connected via a coupling rod

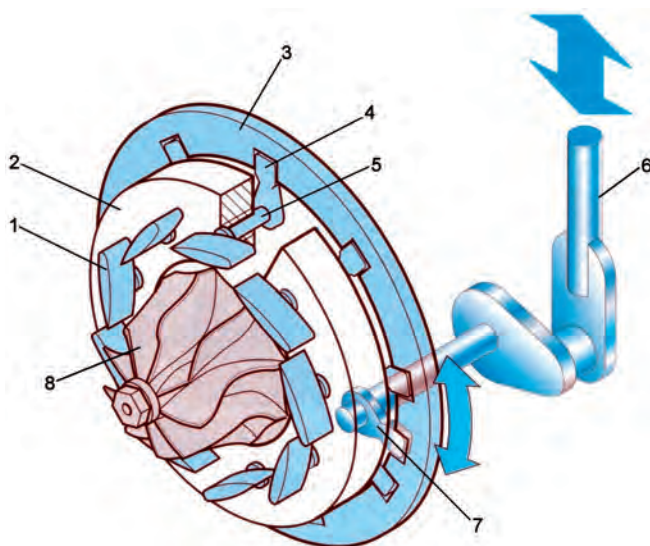
to an adjusting ring. If the adjusting ring is twisted, the angle of the guide blades in the adjusting ring automatically change in relation to the exhaust turbine wheel. The exhaust gas flow from the cylinders after combustion is guided onto the turbine of the turbocharger in a variable and targeted manner.

With variable turbine geometry, small turbochargers are simulated by closed guide blades (small blade gap) and large turbochargers by open guide blades (large blade gap). With the respective advantages, variable turbine geometry permits both very good responsiveness with high torque values even at low engine speeds, as well as high output values at high engine speeds. The high torque is therefore available for a significantly larger engine speed range.

Exhaust Gas Temperature Sensor

A exhaust gas temperature sensor is installed in the housing of the VTG turbocharger; this sensor measures the exhaust gas temperature of the exhaust tract. If the DME control unit detects exhaust gas temperatures that are too high, it reduces the engine power to protect the VTG turbocharger from becoming damaged by the heat.

Function of the VTG Turbocharger



- 1 Guide blades
- 2 Support ring
- 3 Adjusting ring
- 4 Guide pin
- 5 Shaft
- 6 Coupling rod
- 7 Linkage guide pin
- 8 Exhaust gas turbine wheel with turbine blades

The principle of variable turbine geometry is essentially based on the following two physical characteristics:

- Variable blade gap
- Variable air impact angle

The variable blade gap is achieved by turning the adjusting ring and therefore turning the guide blades.

Increasing the Boost Pressure



At low engine speeds, there is less exhaust gas available for driving the exhaust gas turbine.

Fuel, Exhaust & Engine Electrical

To achieve a high boost pressure, even at low engine speeds, the DME control unit adjusts the VTG turbocharger guide blades to a flat angle, therefore:

- The gap between the guide blades and therefore the flow cross-section which the exhaust gas flows through is decreased. The exhaust gases are transported to the exhaust gas turbine blades through the small flow cross-section more quickly
- The exhaust gases are transported outwards to the turbine blades, therefore producing a pronounced leverage effect to the turbocharger shaft

The turbocharger speed and the boost pressure increase, the air mass and the air density rise and fresh air charging is improved. This results in dynamic torque which improves the responsiveness of the engine.

Boost Pressure Limitation

At high load and engine speed, a large quantity of exhaust gas is available to drive the exhaust turbine. The DME control unit checks the existing boost pressure using the boost pressure sensor, which is installed on the connecting piece of the hoses coming from the charge-air coolers.

The air temperature sensor (NTC 1) is also installed in the housing of the boost pressure sensor. The DME control unit also uses information on the air temperature to control the boost pressure, as the air temperature determines the density and therefore the air mass of the air transported into the cylinder.

To limit or reduce the boost pressure, the VTG turbocharger control electronics are activated, thereby setting the guide blades to a steeper angle, therefore:

- The gap between the guide blades and therefore the flow cross-section which the exhaust gas flows through increases. The exhaust gases are transported to the exhaust turbine blades through the larger flow cross-section less quickly and the exhaust gas speed decreases.
- The exhaust gases are transported further to the inside of the turbine blades, thus reducing the leverage effect to the turbocharger shaft

The turbocharger speed and the boost pressure decrease.

The engine power is throttled/reduced. The engine and the turbocharger are protected against too high boost pressures and therefore against faults being caused.

Flow Damper

A stainless steel Helmholtz resonator is installed on the outlet of the charge air line on the VTG turbocharger. It is designed to eliminate disturbing turbocharger noise.

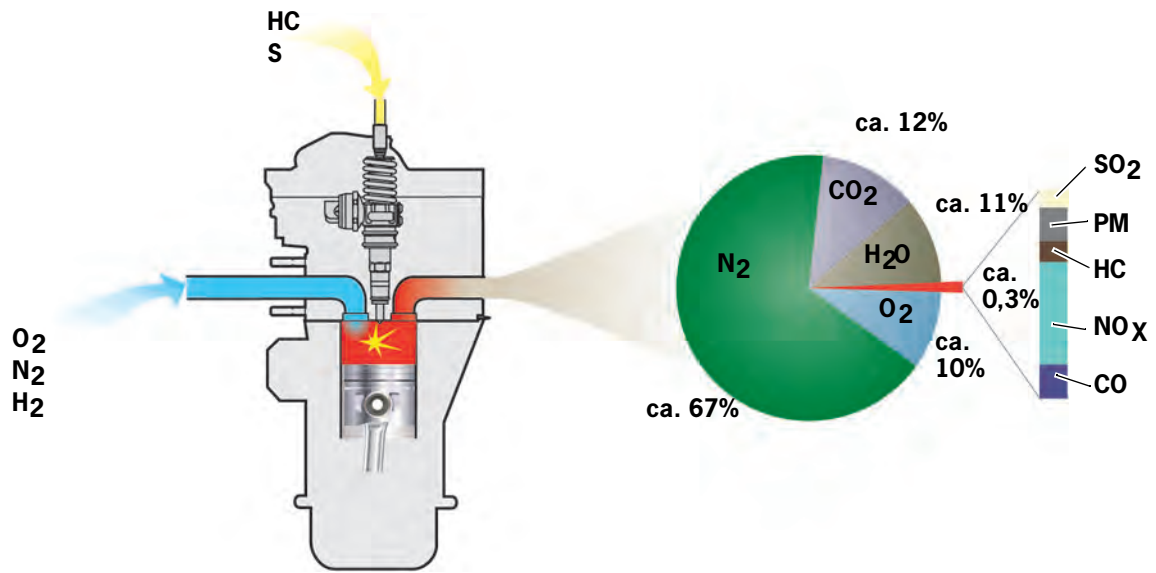
Resonance



Function

At full throttle, the rapidly increasing compression pressure on the fresh air side can lead to air flow stalling, which generates noise. The charge air makes the resonance element vibrate with approximately the same frequency as the charge air which caused the noise. The two vibrations overlap each other, therefore minimizing noise.

Exhaust Gases from Diesel Engines

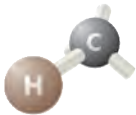


Pollutants



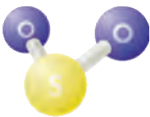
CO - Carbon monoxide

is produced where there is a lack of oxygen during incomplete combustion of carbon. CO is colorless, odorless and tasteless.



HC - Hydrocarbons

fuel largely consists of hydrocarbons; unburned, gaseous fuel also consists of hydrocarbons.



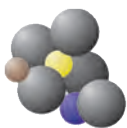
SO₂ - Sulphur dioxide

is produced when fuel containing sulphur is combusted. The sulphur in the fuel also promotes the formation of soot particulate matter. SO₂ is a colorless gas with a pungent odor.



NO_x - Nitrogen oxides

are produced under high pressure, at high temperatures in conjunction with an excess of oxygen.



Soot particles

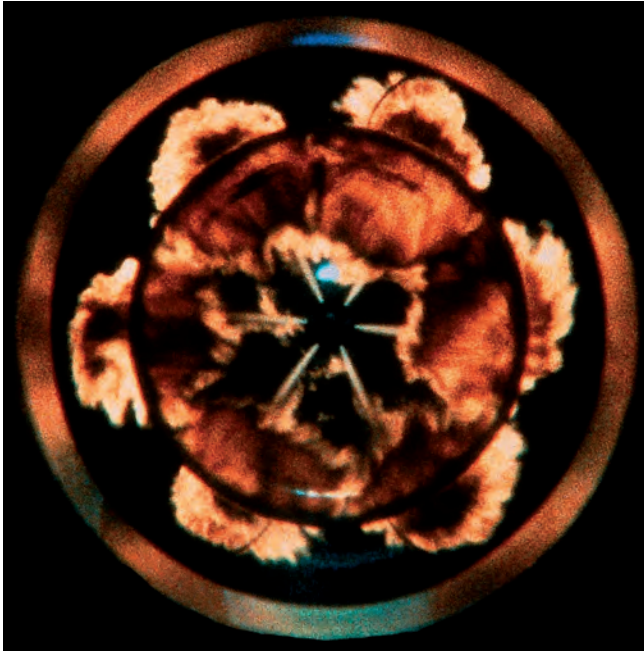
are produced by a variety of different (hydrocarbon) substances in the fuel, particularly in the absence of air; engine technology, fuel quality and conditions of use also impact on the type and quantity of soot particles.

Fuel, Exhaust & Engine Electrical

Measures for Reducing Emissions on the 3.0 I V6 TDI Engine

Exhaust gas emissions are reduced by measures inside and outside of the engine.

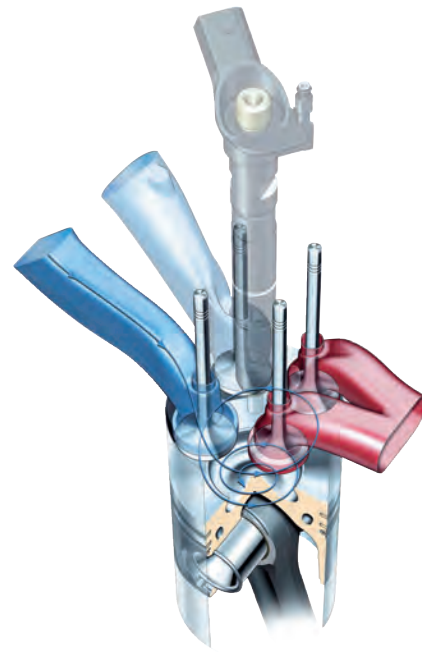
Measures Inside the Engine



An effective measure is not to let exhaust gas emissions develop in the first place.

To achieve this aim, particular demands are made on the

- Intake system,
- Fuel injection system and
- The design of the combustion chamber.



Intake and exhaust port design



High injection pressures combined with optimum atomization due to fine injector outlet holes



Optimized combustion chamber design by reducing the dead space and shaped piston crown (piston recess)

Measures Outside of the Engine

To reduce exhaust gas emissions, the following systems are used with the 3.0 I V6 TDI engine:

- Glow system with rapidly heating glow plugs
- Exhaust gas recirculation system with EGR cooler
- Turbocharging by VTG turbocharger with upstream charge-air cooling
- Broadband oxygen sensor closed-loop control
- Oxidation catalytic converter
- Downstream diesel particulate filter
- SCR system

Exhaust Gas Recirculation (EGR)

In comparison to the gasoline engine, the exhaust gas recirculation rates are higher with the diesel engine, as the diesel engine works with excess air. Similar with the gasoline engine, exhaust gas recirculation in a diesel engine is designed to reduce nitrogen oxide emissions.

By mixing exhaust gases in relation to the aspirated air mass, the oxygen component of the aspirated gases is reduced. This causes the combustion chamber temperature to decrease. As the returned exhaust gas has good heat absorbing properties, the combustion chamber temperature is reduced even more. The nitrogen oxide emissions decrease as the combustion chamber temperature are reduced, therefore the exhaust gas characteristics of the engine are positively affected by exhaust gas recirculation.

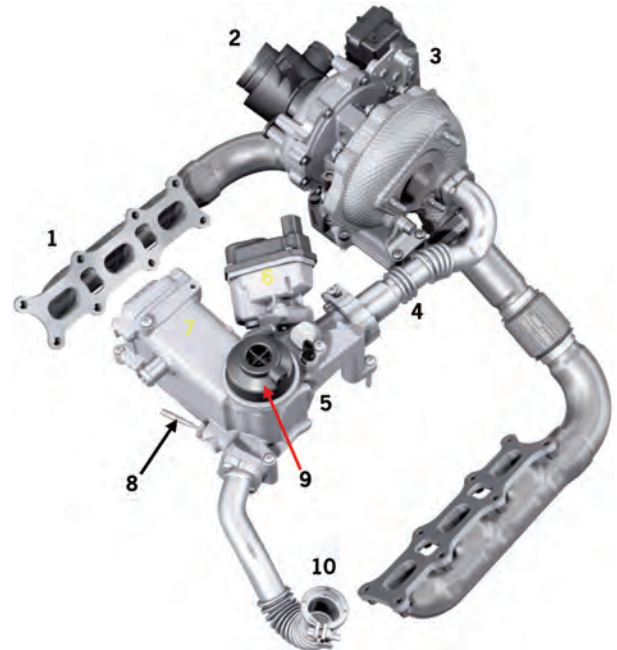
Exhaust gas recirculation is deactivated at:

- Low engine temperature
- High engine speeds
- High load
- Low ambient pressure

At idle speed, small exhaust gas quantities are recirculated if required. The highest exhaust gas recirculation rates are attained in part-load range. In order to increase the exhaust gas recirculation rates, a throttle valve is installed in the intake area of the 3.0 I V6 TDI engine; the valve is controlled appropriately by the DME control unit. (See Intake system, EGR module section) The EGR module has a complex design and consists of several systems.

If the DME control unit decides that exhaust gas recirculation should take place, it activates the electronic servo motor for EGR using pulse width modulation. The servo motor opens the EGR valve and therefore establishes a connection from the exhaust gas area to the intake area. A metered volume of gas flows into the intake area.

The integrated potentiometer, fixed to the servo motor, supplies the DME control unit with feedback about the position of the EGR valve, also providing it with diagnosis capability.

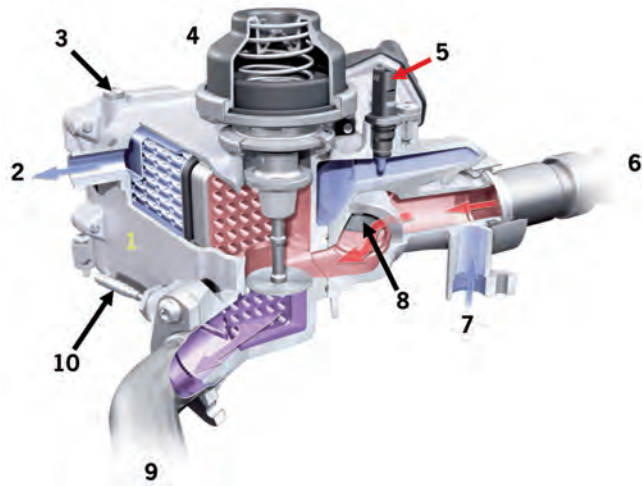


- 1 Air-gap insulated exhaust manifold
- 2 Helmholtz resonator
- 3 VTG turbocharger
- 4 Exhaust gas supply
- 5 EGR module
- 6 EGR valve actuating unit
- 7 EGR cooler
- 8 EGR exhaust-gas temperature sensor
- 9 EGR cooler bypass valve
- 10 Exhaust gas supply

In addition to switching on the throttle valve in the intake area, the exhaust gas recirculation rate can also be increased by the switch on/switch off, water-cooled EGR cooler if the engine is warm. When the exhaust gases are cooled, their density and therefore their mass increases.

Fuel, Exhaust & Engine Electrical

Switch on/Switch off EGR Cooler



- 1 EGR cooler
- 2 Coolant drain (to oil filter module thermostat housing)
- 3 Bleeder screw
- 4 EGR cooler bypass valve
- 5 DME coolant temperature sensor
- 6 Exhaust gas supply (from VTG turbocharger)
- 7 Coolant intake from cylinder head
- 8 EGR valve
- 9 Diverter for exhaust gases to intake manifold
- 10 EGR exhaust-gas temperature sensor

The exhaust gas recirculation radiator is bypassed by the bypass valve (valve open) if:

- The engine is colder than 131° F (55° C)
- The coolant temperature in the main radiator at the radiator outlet is less than 64° F (18° C), or more than 158° F (70° C)
- The engine is idling
- The exhaust gas temperature at the EGR cooler is less than 248° F (120° C)
- The ambient temperature is less than 61° F (16° C)

Notes:

The EGR cooler is by-passed at low temperatures in order that

- The downstream oxidation catalytic converter reaches operating temperature quickly
- EGR cooler sooting is prevented

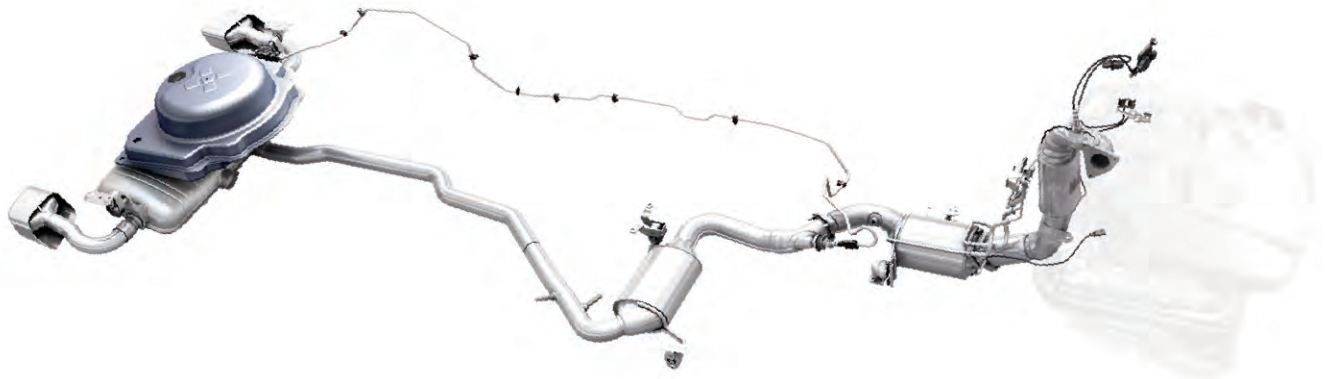
The DME control unit identifies the current engine temperature using information from the engine temperature sensor (NTC 2) and, if the engine is at operating temperature, it activates the electro-pneumatic bypass "poppet type valve. The electro-pneumatic valve " no longer applies ambient pressure, it applies vacuum generated by a vacuum pump to the vacuum unit. The vacuum unit retracts and adjusts the bypass valve so that the exhaust gases to be recirculated are transported via the water-cooled EGR cooler.

Important!

A vacuum pump driven by the engine oil pump is installed in the 3.0 I V6 TDI engine. The vacuum pump is needed because, as opposed to the gasoline engine, insufficient vacuum is produced in the intake manifold of diesel engines.

To monitor the temperature, an exhaust gas temperature sensor (PTC) is installed in the EGR module, behind the bypass valve, which supplies information to the DME control unit about the current exhaust gas temperature. The DME control unit uses this information to optimize exhaust gas recirculation.

Exhaust System



Design of the Cayenne Diesel Exhaust System

Broadband Oxygen Sensor

The broadband oxygen sensor is installed in the exhaust pipe behind the VTG turbocharger and in front of the oxidation catalytic converter. The broadband oxygen sensor can measure the oxygen component in the exhaust gas extremely accurately across the entire engine operating range and it forwards this information to the DME control unit. The signal from the oxygen sensor is used in conjunction with signals from other evaluation electronics sensors in order to determine the load condition of the diesel particulate filter.

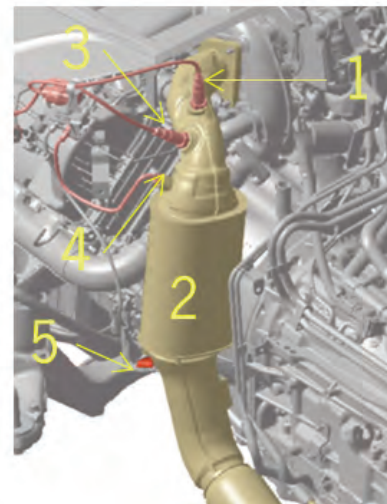
The sensor signal is also used to correct the exhaust gas recirculation quantity. If the signal fails, the exhaust gas recirculation quantity is determined using the Mass Air Flow (MAF) signal. As a result of a failure regulation is not very precise, nitrogen oxide emissions may increase. Calculation of diesel particulate filter contamination is less accurate. However, regeneration of the diesel particulate filter remains reliable.

Oxidation Catalytic Converter

The design of the oxidation catalytic converter used in the 3.0 I V6 TDI engine is comparable with a 3-way catalytic converter for a gasoline engine. As opposed to the catalytic converter for the gasoline engine, the diesel catalytic converter can only convert (oxidize) the following substances.

Carbon monoxide (CO)	→	Carbon dioxide (CO ₂)
Hydrocarbons (HC)	→	Water (H ₂ O)
Nitric oxide (NO)	→	Nitrogen dioxide (NO ₂)

The start-up temperature of the diesel oxidation catalytic converter is 338° F (170° C), far below that for the 3-way gasoline catalytic converter, due to the large oxygen component in the diesel engine exhaust gas. The oxidation catalytic converter is an essential requirement for exhaust gas post treatment systems with diesel particulate filters, as the nitrogen dioxide (NO₂) generated in the oxidation catalytic converter reduces the ignition temperature of the soot particles to approx. 662° F (350° C) and therefore supports natural regeneration of the diesel particulate filter.



- 1 Broadband oxygen sensor
- 2 Oxidation catalytic converter
- 3 NO_x Sensor (pre cat)
- 4 Temperature Sensor (pre cat)
- 5 Temperature Sensor (post cat)

Fuel, Exhaust & Engine Electrical

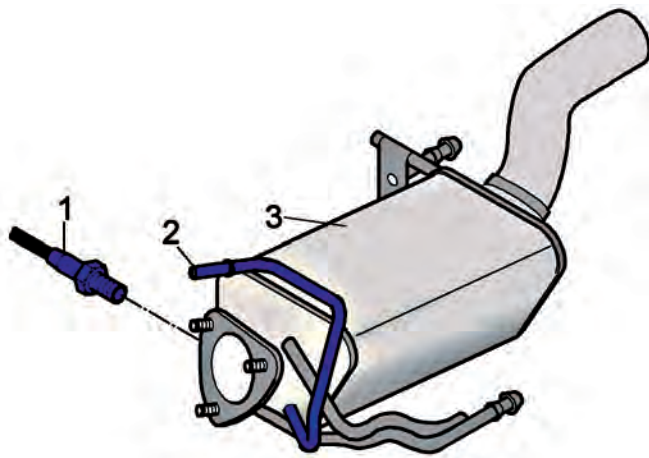
The oxidation catalytic converter also provides other advantages for the diesel particulate filter due to the oxidation of HC (hydrocarbons) and CO (carbon monoxide), as additional heat is generated which helps the particle filter to heat up, therefore assisting regeneration. Exhaust gas temperatures are measured in four different locations through out the exhaust system (prior to entering the turbocharger, pre cat, post cat, and post DPF) by a PTC type exhaust gas temperature sensor.

The higher the temperature is in the regeneration phase, the smaller the injected fuel volume for post-injection will be. This reduces fuel consumption and exhaust gas emissions. The heat from the oxidation catalytic converter also prevents the diesel particulate filter from cooling down too quickly during deceleration.

Diesel Particulate Filter (DPF)

The diesel particulate filter is a highly-effective exhaust gas post-treatment system which is used to reduce soot particle emissions.

Design

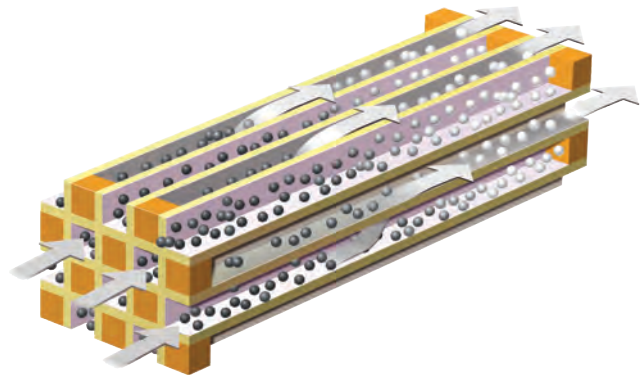


- 1 Exhaust gas temperature sensor
- 2 Connection for relative pressure sensor
- 3 Diesel particulate filter

It has a similar appearance to a catalytic converter. However its internal design is fundamentally different to a catalytic converter. A cerioxide and platinum-coated, porous silicon carbide ceramic monolith is used as the filter material, which is formed into honeycomb shaped ducts.

The platinum coating ensures that, from a temperature of just under 392° F (200° C), additional NO₂ is produced in order to lower the ignition temperature of the soot particles and to facilitate natural regeneration. The cerioxide coating accelerates active regeneration of the particulate filter above 1076° F (580° C) by forming oxygen (O₂).

Down stream of the DPF a temperature sensor measures the exhaust temperature. the DME calculates the amount of contamination in the DPF in conjunction with other sensor signals (other exhaust gas temp sensors, exhaust pressures, mass air flow sensor, oxygen sensor). This signal also serves as component protection input to protect the DPF against excessively high exhaust gas temperatures. In the event of a failure DPF regeneration takes place according to distance traveled or hours of operation.



The honeycomb elements ends of the diesel particulate filter are blocked off alternately. This forces the exhaust gases to flow through the filter material. However, the filter material only allows gaseous components and no solid particles through, therefore the soot particles from the combustion chamber remain in the particle filter ducts. Other solid components in the exhaust gas, such as abraded metal matter, oil and fuel residue, are also collected by the filter. The filter clogs up more and more and the back pressure caused by the filter increases.

Coated Zones

The diesel particulate filter must be long enough to provide sufficient storage volume for the carbon soot. In addition, it must be coated with a certain amount of platinum in order to attain the desired catalytic effect. The catalytic coating of the diesel particulate filter is separated into zones across the length of the filter.

In the front zone, there is a large quantity of platinum and in the rear zone there is less platinum. The following are advantages from the zone-like coating:

- In normal operating modes of the engine, the diesel particulate filter heats up quickly in the front area. Due to the high concentration of platinum in this front zone of the catalyst, the filter has a very fast catalytic effect. The diesel particulate filter responds quickly.
- In regeneration mode, the rear area of the diesel particulate filter becomes very hot as the carbon soot is burned off. Due to these high temperatures, the platinum gets broken down over a period of time. Therefore, expensive raw material is not used as intensively at the rear zone.
- Another reason for reduced use of platinum in the rear zone is the aging of the diesel particulate filter. During operation, more and more ash particulates from regeneration stay in the filter. These impair the catalytic effectiveness of the platinum.

Diesel Particulate Filter Load

The load condition of the diesel particulate filter is measured by the DME control unit by means of two pre-programmed load models. With one load model, the DME control unit analyses various pre-saved parameters and derives the driving profile from it. On the basis of this driving profile, the DME control unit uses an electronically-saved map to calculate the load condition of the diesel particulate filter.

The DME control unit analyses the following data in order to determine the condition of the diesel particulate filter:

- Differential exhaust gas pressure
- Residual oxygen content in the exhaust gas
- Distance travelled
- Engine speeds
- Air mass
- Coolant temperatures
- Exhaust gas temperatures

The signal from the broadband oxygen sensor is, for example, used to determine the quantity of emitted soot particle emissions on the basis of the oxygen component in the exhaust gas. If the oxygen component in the exhaust gas is less than its setpoint, this is taken as an indication of increased soot emissions.

The second load model analyses the data from the

- Differential pressure sensor
- Exhaust gas temperature sensor
- Mass air flow sensor

One of the most important factors is the relative pressure of the exhaust gas in relation to the exhaust gas volume flow. The DME control unit uses this value to determine whether there are any defects on the particle filter, for example very low exhaust pressure indicates a hole in the particle filter. High exhaust pressure indicates that the diesel particulate filter is either loaded or overloaded.

Differential Pressure Sensor

The Differential Pressure Sensor is fixed to the bulkhead of the plenum panel, in the center of the engine. The Differential Pressure Sensor measures the difference in pressure in the flow of exhaust gas upstream and downstream of the diesel particulate filter. The DME uses the Differential Pressure Sensor signal to calculate the amount of contamination in the diesel particulate filter. The diesel particulate filter contamination status is calculated using the Differential Pressure Sensor, together with the signals from the Exhaust Gas Temperature Sensors, the Mass Air Flow Sensor, and the Heated Oxygen Sensor. If the Differential Pressure Sensor fails DPF regeneration takes place according to distance traveled or hours of operation.

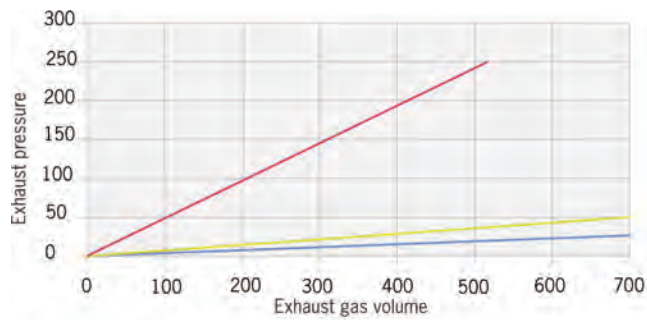
Exhaust Gas Volume Flow

The DME control unit also measures the fresh air mass using the mass air flow sensor. The fresh air mass value is similar to the exhaust gas mass. In conjunction with the exhaust gas temperature measured by the exhaust gas temperature sensor ahead of the diesel particulate filter, the DME control unit calculates the exhaust gas volume flow.

Fuel, Exhaust & Engine Electrical

Determining the Load Condition

The DME control unit compares the exhaust gas pressure measured with the volume flow measured and, on the basis of an electronically-saved map, it identifies the current load condition of the diesel particulate filter.



Load condition of the diesel particulate filter



Diesel Particulate Filter Regeneration

After the diesel particulate filter has filtered the solid soot particles out of the exhaust gas, it becomes more and more clogged with the particles and the back pressure to the cylinders rises more and more as the load increases. The particle filter needs to be regenerated.

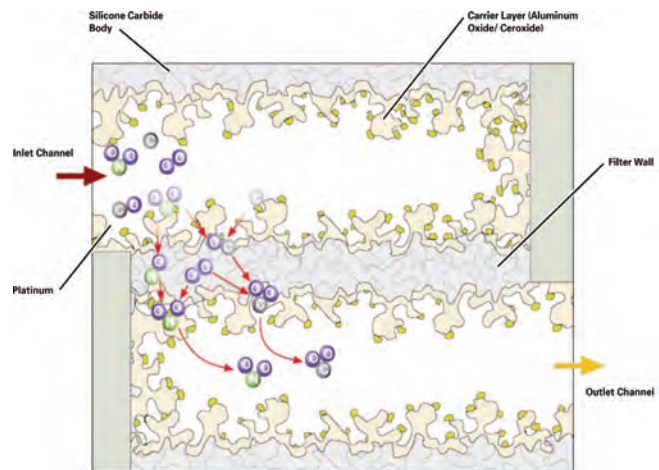
During the diesel particulate filter regeneration phase, the collected soot particles are converted into CO₂ (carbon dioxide) and H₂O (water) due to the action of heat.

Regeneration of the diesel particulate filter consists of the following phases:

- Passive (natural) regeneration
- Heating phase
- Active regeneration
- Regeneration drive cycle by the driver
- Artificially induced regeneration at the workshop with PIWIS Tester II

1. Passive (natural) Regeneration

With passive regeneration, the carbon soot particles are burned off continually without intervention from the engine management system. The particulate filter is positioned in close proximity to the engine. This assures that exhaust gas temperatures of 660–932° F (350–500° C) are reached during highway driving. The carbon soot particles are converted into carbon dioxide by a reaction with nitrogen oxide. This gradual process occurs slowly and continually through the platinum coating, which works as a catalyst.



From the oxides of nitrogen present in the exhaust gas (NO_x) and oxygen (O₂), nitrogen dioxide (NO₂) is produced via the platinum coating. NO_x + O₂ reacts to NO₂. The nitrogen dioxide (NO₂) reacts with the carbon (C) of the carbon soot particles. As a result, carbon monoxide (CO) and nitrogen monoxide (NO) are formed. NO₂ + C reacts to CO + NO. The carbon monoxide (CO) and nitrogen monoxide (NO) combine with oxygen (O₂) and form nitrogen dioxide (NO₂) and carbon dioxide (CO₂). CO + NO + O₂ reacts to NO₂ + CO₂.

2. Heating Phase

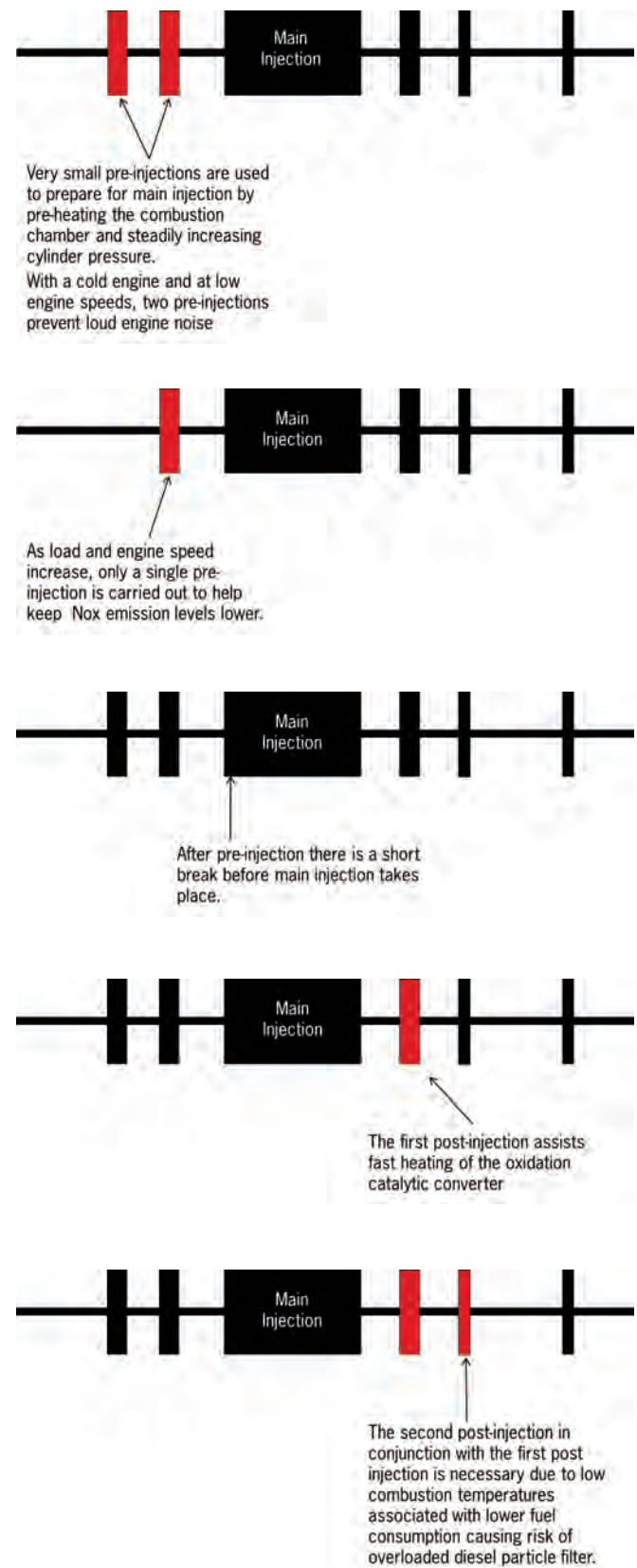
To bring the diesel particulate filter with upstream oxidation catalytic converter up to its operating temperature as quickly as possible:

- Exhaust gas recirculation is deactivated
- The DME control unit delays the main injection
- The boost pressure is increased in order to compensate for the loss of power caused by delayed injection
- The engine management system triggers specific post-injections after the main injection
- The DME control unit switches the throttle valve on in order to control the volume of intake air
- The glow system is switched to the “interim heating” function in the event of low load and engine speed

Initially, the DME control unit works with one post-injection which takes place just before the outlet valve is opened, it therefore does not contribute to increasing the engine torque but ensures that very hot exhaust gases reach the catalytic converter. As soon as the DME control unit identifies the operating temperature via the PTC exhaust gas temperature sensor behind the oxidation catalytic converter, the second post-injection is activated if needed to support increasing the exhaust gas temperatures.

The disadvantage of the lower fuel consumption is that the combustion chambers cool down. The injection strategy therefore had to be adapted to achieve the necessary regeneration temperatures. Rather than just compensating for the temperature deficit, the additional post-injection improves it. The probability of requiring artificial regeneration initiated by PIWIS Tester II in the workshop is further reduced.

Injection Phases



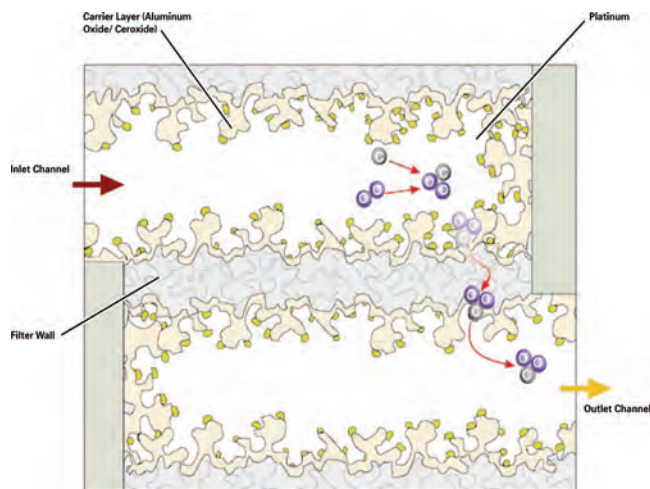
Fuel, Exhaust & Engine Electrical

3. Active Regeneration

During the regeneration phases, the main injection is initially followed by two post-injections close to the combustion point this is where most of the thermal energy is produced for post exhaust gas treatment. The third post-injection takes place later on its own. The purpose of the third post-injection is to produce an exothermic reaction in the oxidation catalytic converter; it uses very small injection quantities and helps to achieve the necessary ignition temperature for the diesel particles in the filter.

During the exothermic reaction, the fuel injected when the outlet valves are open reach the oxidation catalytic converter without igniting in a gases state. The fuel is converted into heat in the oxidation catalytic converter without a flame forming. The additional heat is transported into the diesel particle filter by the exhaust flow.

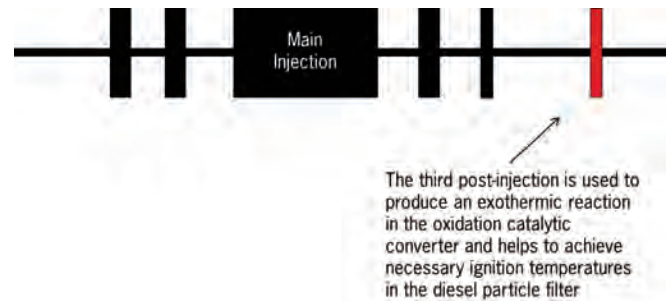
With active regeneration, the carbon soot particles are burned off through a targeted increase in the exhaust gas temperature by the engine management system. In city traffic, which produces low loads on the engine, the exhaust gas temperatures for passive regeneration of the particulate filter are too low. Since the carbon soot particles cannot be broken down, deposits build up in the filter. As soon as a certain level of carbon soot deposits is reached in the filter, active regeneration is initiated by the engine management system. This process lasts for approximately 10 minutes. The carbon soot particles are burned off to carbon dioxide at an exhaust gas temperature of 1110–1200° F (600–650° C).



With active regeneration, the carbon soot particles are burned off by high exhaust gas temperatures. When this

happens, the carbon from the soot particles oxidizes with oxygen and forms carbon dioxide. $C + O_2$ reacts to CO_2 .

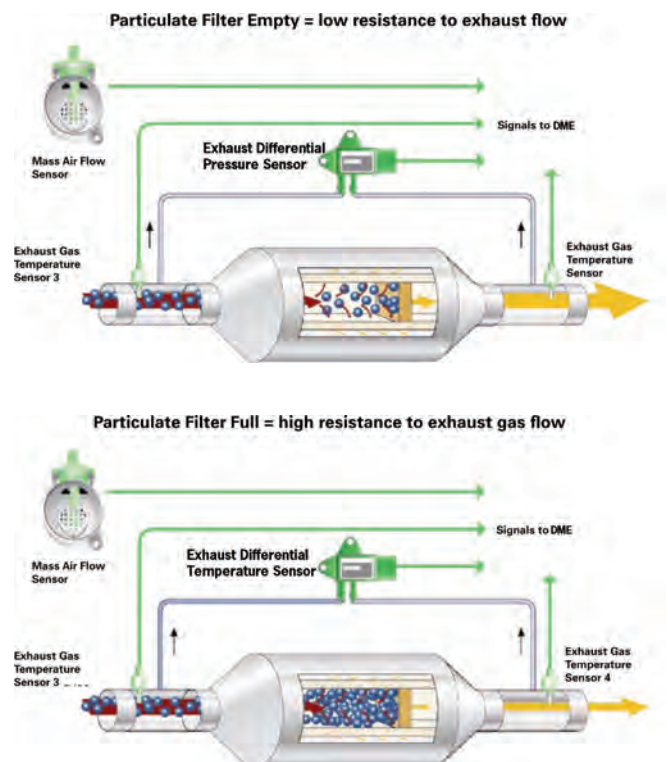
The DME control unit checks the temperature using the exhaust gas temperature sensor in the particle filter and, if required, deactivates the post-injections to prevent components from overheating.



In chemistry, an exothermic reaction (usually chemical) is one where energy is released into the surroundings in the form of heat.

Function of Active Regeneration

The DME control unit can detect the level of carbon soot in the particulate filter by evaluating the signals from the mass air flow sensors, the temperature sensors before and after the particulate filter, and the exhaust pressure sensors. When the carbon soot level reaches a predetermined limit, the engine management system initiates active regeneration.



DME Interaction at Start of Active Regeneration

From the flow resistance of the particulate filter, the DME control unit can detect the level of carbon soot deposit in the filter. A high flow resistance indicates that the filter is in danger of becoming blocked. The DME control unit initiates an active regeneration process.

To do this:

- Exhaust gas recirculation is switched off to raise the combustion temperature
- The DME control unit adapts the injection strategies with regard to main and post injections, in order to increase the exhaust gas temperature
- The intake air supply is regulated by the throttle valve
- The charge air pressure is adapted so that the torque during regeneration does not change noticeably by the driver

These measures lead to a targeted, brief increase in the exhaust gas temperature to approximately 1150° F – 1200° F (600° C – 650° C). In this temperature range, the collective carbon soot oxidizes to carbon dioxide. After this active regeneration period, the particulate filter is ready for operation again and can begin filtering carbon soot out of the exhaust gas.

4. Regeneration Drive Cycle by the Driver

If only short distances are driven, the exhaust gas temperatures needed for regeneration are not attained. A limit value for the load condition of the diesel particulate filter is stored in the DME control unit. If this limit value is reached the driver is informed by the “Check diesel particulate filter” message on the instrument cluster.

The driver should then carry out regeneration by driving for 15 minutes at a minimum of 37 mph (60 km/h) with an engine speed of more than 2000 rpm in order to trigger regeneration. If the error message does not disappear, the driver must drive the vehicle to the nearest authorized workshop. In the event that the driver does not comply with the regeneration request or if the driver does not drive to a workshop after a failed regeneration attempt, the load condition of the particle filter will continue to increase. If the measured relative particle filter pressure is too high, the DME control unit reduces the engine power, the “Engine workshop” error message appears on the instrument cluster display and the glow indicator light is activated.

5. Artificially induced regeneration at the workshop

If it was not possible for the customer to initiate diesel particulate filter regeneration, the customer must drive the vehicle to the workshop. A technician can use the PIWIS Tester II to start artificially induced regeneration. An artificially induced regeneration triggered by the PIWIS Tester follows a defined program.

The DME Control Unit

- Increases the injection pressure to the maximum
- Activates various electrical loads which require a great deal of power
- Increases the engine speed
- Initiates post-injections

in order to attain the necessary regeneration temperature and to maintain it until the particle filter has regenerated.

There are various reasons why an artificially induced regeneration is required and why it may be unsuccessful:

1. The driver disregards the regeneration request or only complies with it when it is too late.
2. The differential pressure sensor is faulty and reports the wrong load condition to the DME control unit.
3. The vehicle has been topped up and driven with the wrong engine oil.
4. Other technical defects, e.g. a defective diesel particulate filter

During regeneration, only the soot particles can be burnt and not:

- Abraded metal matter
- Other soiling
- Sulphur
- Oil ash

Fuel, Exhaust & Engine Electrical

Poor-quality fuel often has a higher sulphur content than high quality fuels. The sulphur released during combustion clogs the pores of the diesel particulate filter and blocks it. If the regeneration interval becomes shorter and shorter the DME control unit assumes that the filter is loaded with sulphur or soiling of another kind and it records a fault to this effect in the fault memory. In exceptional cases, replacing the diesel particulate filter may be necessary. However, the diesel particulate filter usually lasts for the entire service life of a vehicle and does not have to be replaced.



Danger!

The artificially induced regeneration must not be carried out inside the workshop under any circumstances as the exhaust gas temperatures generated during regeneration cause thermal overload on the exhaust gas tubes. Therefore regeneration must only be carried out in the open air where there is no risk of fire.



Note!

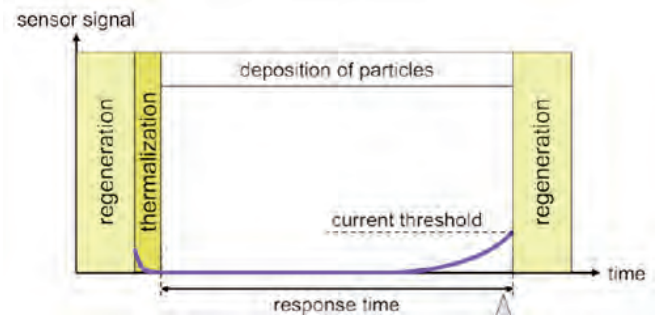
Use only approved engine oil, see Workshop Manual.

Soot Sensor



The efficiency of the diesel particulate filter has to be monitored. That is why a soot sensor is located downstream the diesel particulate filter and the SCR catalyst. The sensing element consists of two electrodes with an infinite electrical resistance, an internal heater and a temperature element.

During the deposition of soot particles from the exhaust gas, an electrical contact is formed between the electrodes so that the electrical resistance starts to decrease. After a certain time a pre-defined current threshold is reached and the heater element heats the sensor above soot ignition temperatures for burning off the adsorbed soot.



The time between the start of the measurement and the start of burning off (regeneration) is defined as the response time, which correlates with the soot concentration in the exhaust pipe. The response time is used for the diagnostics function.

Fuel Quality

As per the Owners Manual – Risk of engine damage and/or damage to the fuel system if diesel fuel with a higher concentration of sulfur than ULSD (Ultra Low Sulfur Diesel) is used.

Only use ULSD (Ultra Low Sulfur Diesel) ASTM-D-975 (grade 2).

Risk of engine damage and/or damage to the fuel system if diesel fuel with a higher concentration of biodiesel than 5 % is used like B11, B20 or B100.

Only use diesel fuel with a blend of 5 % biodiesel (B5) or below.

Selective Catalytic Reduction (SCR)



In addition to the continuous improvement of internal combustion within the engine, the global tightening of exhaust emissions limits for passenger cars and commercial vehicles with diesel engines also necessitates increasingly higher-performance exhaust gas after treatment systems. The SCR system is used to reduce the nitrogen oxides contained in exhaust gas. The abbreviation SCR stands for Selective Catalytic Reduction. With this technology, the chemical reaction of reduction is selective. This means that, out of all exhaust gas emissions, only the nitrogen oxides are specifically reduced. In the reduction catalytic converter, the nitrogen oxides (NO_x) contained in the exhaust gas are converted into nitrogen (N_2) and water (H_2O). To achieve this, a reducing agent is injected into the exhaust gas flow upstream of the reduction catalytic converter. The reducing agent is contained in a separate, additional tank.

Nitrogen Oxides

Nitrogen oxides are the collective term for chemical compounds consisting of nitrogen and oxygen (e.g. NO , NO_2 ...). They occur during combustion in the engine as a result of high pressure, high temperatures and surplus oxygen.



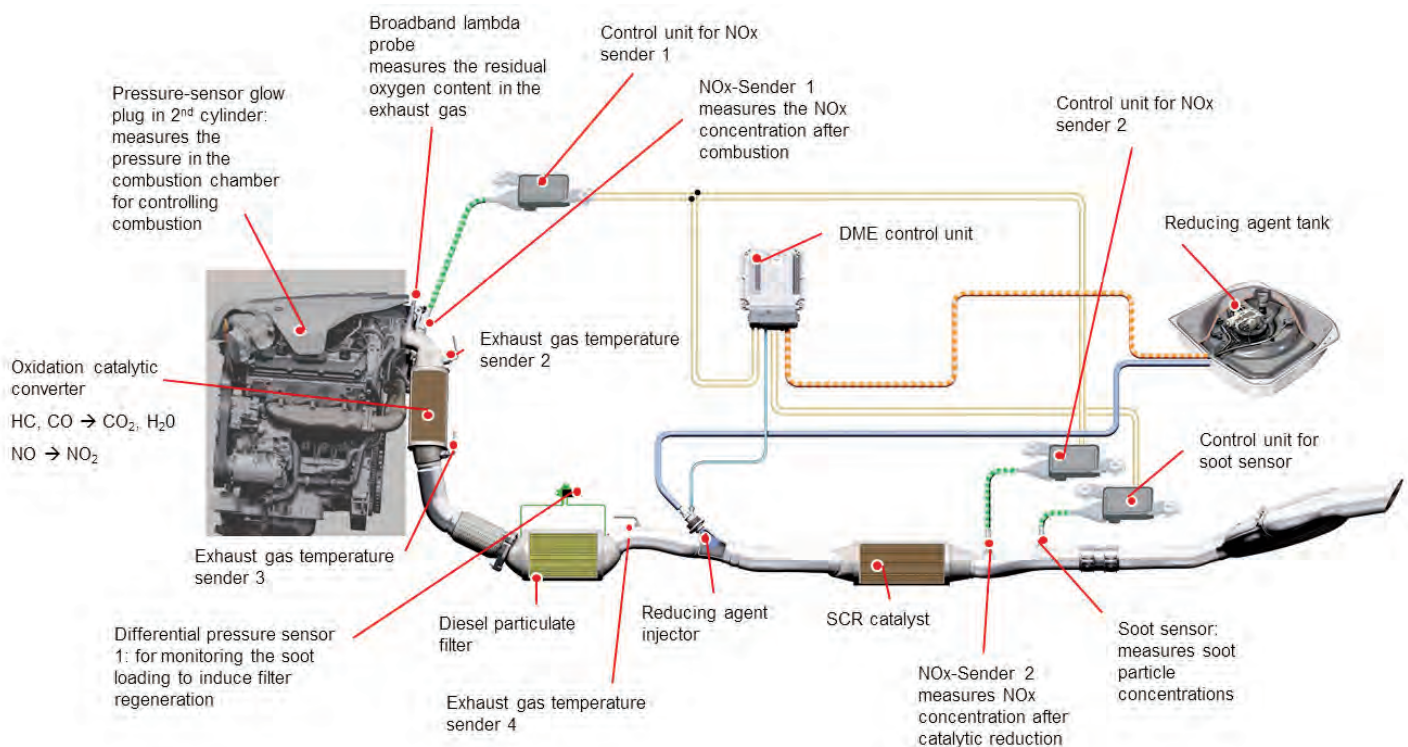
Nitrogen Oxide Reduction Measures

Emission reduction can be achieved via measures within the engine. Effective optimization of combustion ensures that pollutants do not occur in the first place.

The measures within the engine include:

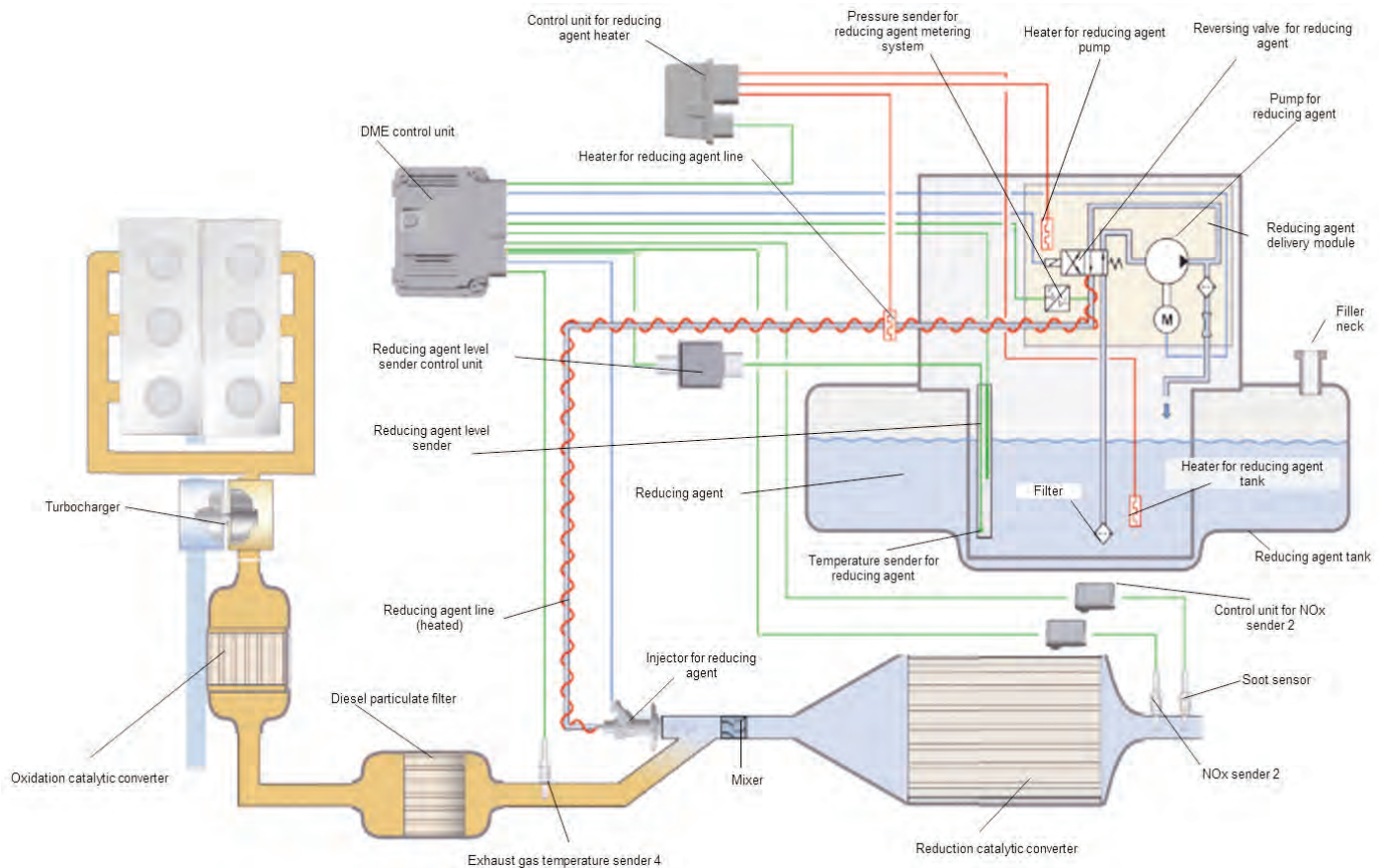
- Designing intake and exhaust ports for optimal flow conditions
- High injection pressures for good mixture formation
- The design of the combustion chamber, e.g. the design of the piston recess and the reduction of the compression ratio
- EGR System
- EGR System cooling
- Efficient engine cooling systems

Exhaust System With SCR System



Fuel, Exhaust & Engine Electrical

SCR System (schematic overview)



Functional Principle of the SCR System

The reduction catalytic converter has reached its operating temperature at approximately 392° F (200° C). Information on the reduction catalytic converter's exhaust gas temperature is received by the DME control unit from exhaust gas temperature sender 4. The AdBlue® reducing agent is sucked out of the reducing agent tank by the reducing agent pump and sent through the heated supply line to the injector for reducing agent at a pressure of approx. 72.5 psi (5 bar).

The injector for reducing agent is actuated by the DME control unit and injects the metered reducing agent into the exhaust system. The injected reducing agent is carried along by the exhaust gas flow and is evenly distributed in the exhaust gas by the mixer. On the route to the reduction catalytic converter, also known as the hydrolysis section, the reducing agent is broken down into ammonia (NH₃) and carbon dioxide (CO₂).

In the reduction catalytic converters, the ammonia (NH₃) reacts with the nitrogen oxides (NO_x) to form nitrogen (N₂) and water (H₂O). The SCR system's efficiency is registered by NO_x sensor 2.

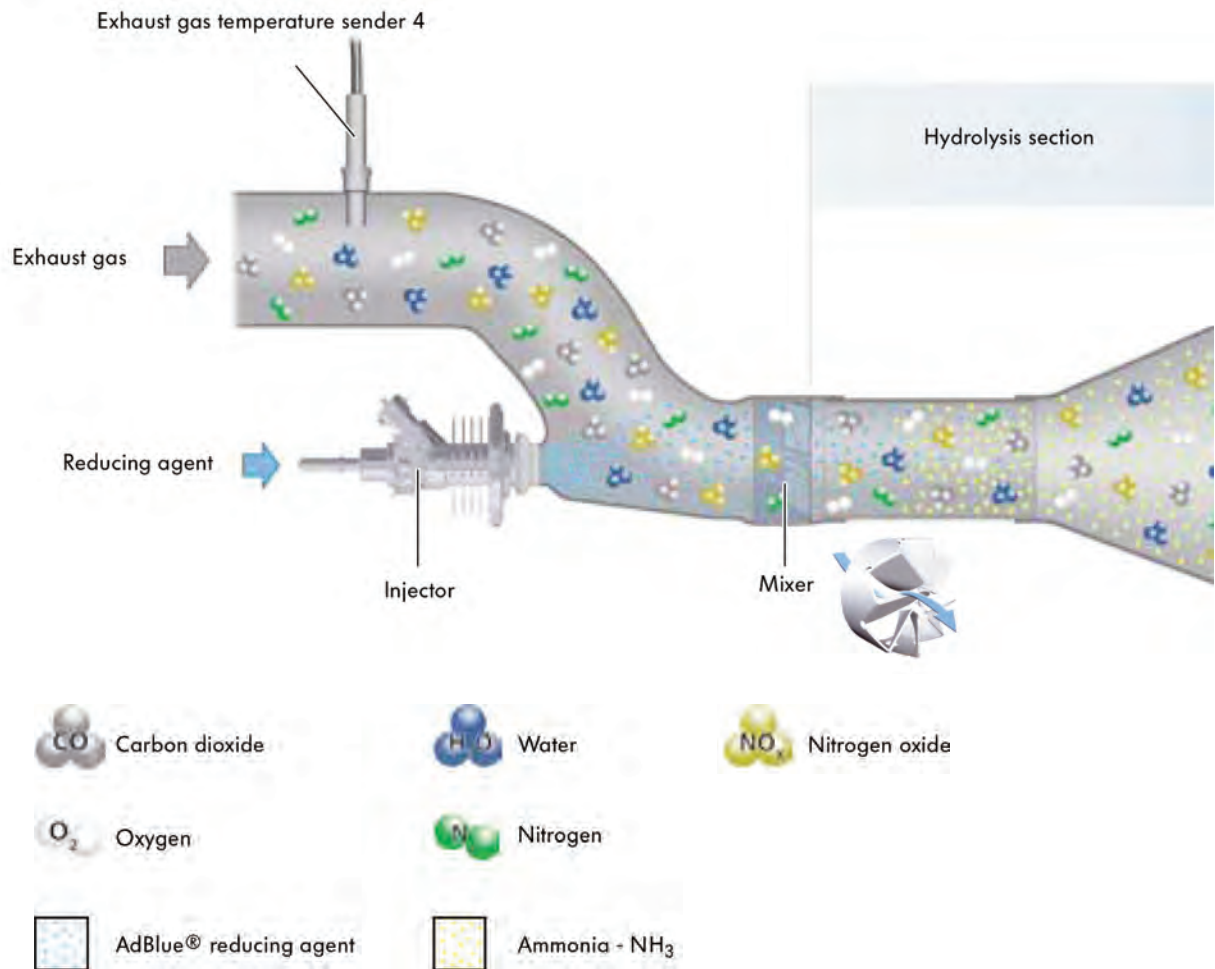
The following prerequisites must be met for the DME control unit to inject the reducing agent:

- The reduction catalytic converter has reached its operating temperature of approx. 392° F (200° C)
- There must be guaranteed that sufficient liquid reducing agent is available for injection at low exterior temperatures.

Under the following conditions, injection of the reducing agent is interrupted by the DME control unit:

- If the mass exhaust gas flow is too low, e.g. during idling.
- If the exhaust gas temperature drops below the reduction catalytic converter's operating temperature.

The design of the reduction catalytic converters corresponds to that of an oxidation catalytic converter with a honeycomb-shaped ceramic body. The reduction catalytic converter's coating consists of copper zeolith. This accelerates the speed of the nitrogen oxide reduction process.



Notes:

Fuel, Exhaust & Engine Electrical

Hydrolysis Section



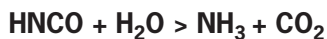
The hydrolysis section is located between the injector for reducing agent and the reduction catalytic converter. The ammonia (NH_3) required to reduce the nitrogen oxides is formed there from the reducing agent (urea solution). This is carried out via a thermolysis and hydrolysis reaction on the part of the injected reducing agent. When the reducing agent is injected into the hot exhaust gas flow, the water initially evaporates.

During thermolysis, the reducing agent (urea solution) is broken down into ammonia and isocyanic acid.



Urea > ammonia + isocyanic acid

This is followed by hydrolysis, in which the isocyanic acid reacts with the water contained in the exhaust gas. This leads to the creation of an additional ammonia and carbon dioxide molecule.



Isocyanic acid + water > ammonia + carbon dioxide

Thermolysis = thermolysis is a chemical reaction in which an initial substance is broken down into several products by way of heating.

Hydrolysis = hydrolysis is the separation of a chemical compound via its reaction with water.

Good mixing and the even distribution of reducing agent and exhaust gas are very important! Before entering the SCR catalytic converter, the reducing agent must have evaporated completely. The more even the distribution, the higher the efficiency of the reduction catalytic converter.

Reduction Catalytic Converter

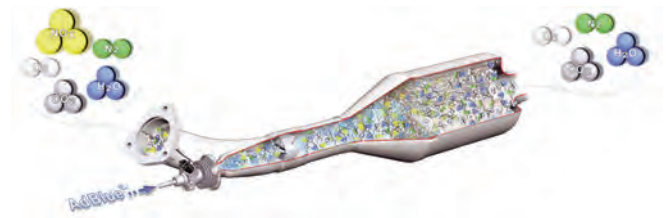
Functional Principle of Nitrogen Oxide Reduction

Nitrogen oxide reduction takes place in the reduction catalytic converters. This means that the nitrogen oxides (NO_x) give up their oxygen molecules during the reduction process or, to express it differently, the oxygen molecules are withdrawn from the nitrogen oxides. In the reduction catalytic converter, the nitrogen oxides ($\text{NO} + \text{NO}_2$) react with the ammonia (NH_3) to form nitrogen (N_2) and water (H_2O).

The correct NO and NO_2 ratio in the exhaust gas for the reduction process is formed in the oxidation catalytic converter. The oxidation catalytic converter's coating is designed for the SCR system.



Nitrogen monoxide + nitrogen dioxide + ammonia > nitrogen + water



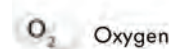
Following the reduction process, the following substances are then contained in the exhaust gas:



Carbon dioxide



Water



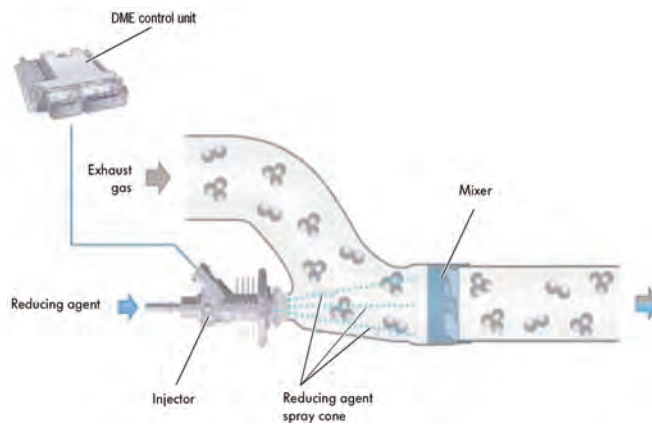
Oxygen



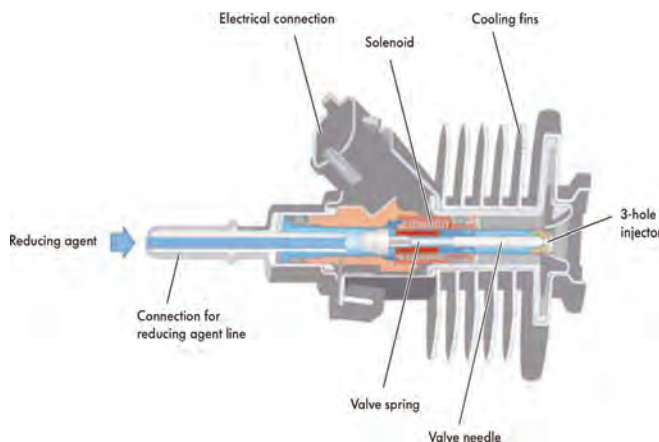
Nitrogen

Injector For Reducing Agent

The injector for the reducing agent has the task of metering the reducing agent into the exhaust gas flow. To do this, it is actuated by the DME control unit with a pulse-width-modulated signal.



Due to the position of the injector on the s-shaped exhaust pipe system, the reducing agent is injected axially to the exhaust gas flow direction. This avoids spray cone deflection and therefore ensures that the reducing agent is mixed well and distributed evenly in the exhaust gas flow. As a result of these design measures, the reducing agent is rapidly and completely mixed into the gas phase.

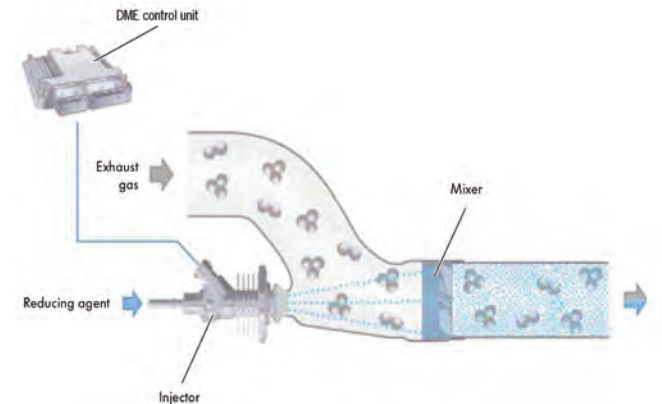


The reducing agent pressure, which is generated by the reducing agent pump, is present at the injector. In its resting position, the valve needle seals the outlet bores due to the valve spring force. The solenoid is actuated by the engine control unit in order to inject the reducing agent. This leads to the creation of a magnetic field, which raises the valve armature and the valve needle. The valve opens and reducing agent is injected. If the solenoid is no longer actuated, the magnetic field collapses and the valve needle closes due to the valve spring force.

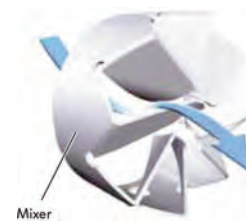
In the event of a defective injector, no reducing agent can be injected into the exhaust system. Adherence to the emission standards is no longer possible. The check engine light and the AdBlue® warning display are illuminated in the instrument cluster and a fault is entered into the fault memory.

Mixer

In the exhaust system, a mechanical mixer for the injected reducing agent is located directly downstream of the s-shaped pipe.



The mixer primarily functions as an impact surface for the injected spray droplets. The position of the plate mixer has been selected in such a way that the spray cone of the injected reducing agent hits the impact surface as much as possible.



On encountering the impact surface, the spray droplets are reduced in size. This allows the injected reducing agent to evaporate and mix into the gas phase faster. It also prevents larger spray droplets from impacting onto the reduction catalytic converter. The geometry of the mixer also causes the exhaust gas flow to swirl. This leads to better mixing and even distribution of the spray droplets in the exhaust gas flow.

Fuel, Exhaust & Engine Electrical

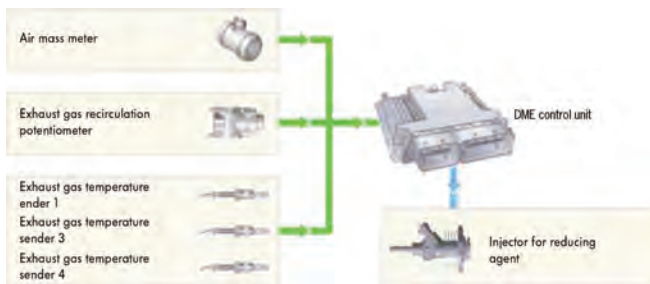
Calculation of the Quantity of Reducing Agent Injected

The required reducing agent injection quantity is calculated by the DME control unit and depends on the following factors:

- Engine operating status
- Exhaust gas temperature
- Nitrogen oxide content in the exhaust gas mass flow

Nitrogen Oxide Content in the Exhaust Gas Mass Flow

The nitrogen oxide content which enters the reduction catalytic converter is determined via a map-dependent calculation model in the DME control unit. The calculation model is based on a theoretical nitrogen oxide content in the exhaust gas mass flow. The exhaust gas mass flow corresponds to the air mass flow in the intake, which is determined by the air mass meter, and the injected fuel mass.

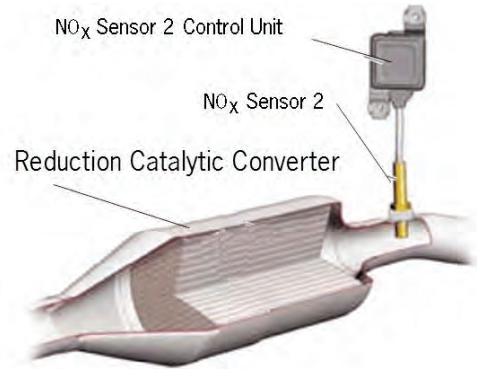


Ammonia Storage in the Reduction Catalytic Converter

At certain engine operating points, e.g. during idling or at low exhaust gas temperatures, ammonia can be stored in the reduction catalytic converter. This stored ammonia is used to reduce a higher percentage of the nitrogen oxides in the exhaust gas under favorable operating conditions. The stored volume of ammonia is also determined using a model calculation in the DME control unit, and is used as an additional influencing parameter in calculating the injected quantity.

NO_x Sensor 2

NO_x sensor 2 is bolted into the exhaust pipe directly downstream of the reduction catalytic converter. The nitrogen oxide content in the exhaust gas is determined with it and is evaluated by the control unit for NO_x sensor 2.



Signal Use

In order to monitor the function of the SCR system, the effectiveness of the reduction catalytic converter is determined with the aid of the signal from the NO_x sensor. To do this, the measured value is compared with a nitrogen oxide calculation model in the DME control unit.

The NO_x sensor's signal currents lie in the microampere range. To achieve high measuring accuracy, the signals are not transmitted via a long line to the DME control unit, but are evaluated over a short route by the control unit for NO_x sensor. The control unit for NO_x sensor processes the signals and transmits them to the engine control unit. The NO_x sensor and the control unit for NO_x sensor form a single unit and must be exchanged together in the event of a fault.

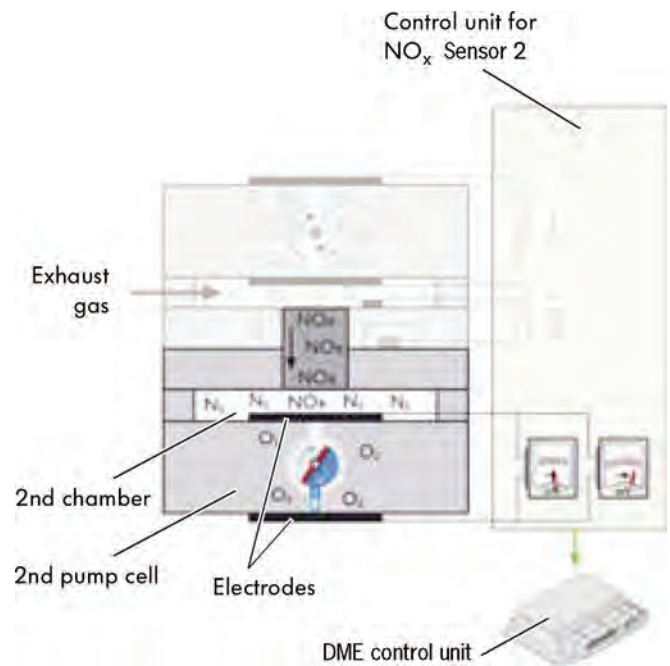
Design

The NO_x sensor consists of two chambers, two pump cells, several electrodes and a heater. The sensor element consists of zirconium dioxide. This substance has the characteristic that, when electrical voltage is applied, the negative oxygen ions migrate from the negative electrode to the positive electrode.

to be measured. Due to different oxygen contents in the exhaust gas and the reference cell, an electrical voltage can be measured at the electrodes.

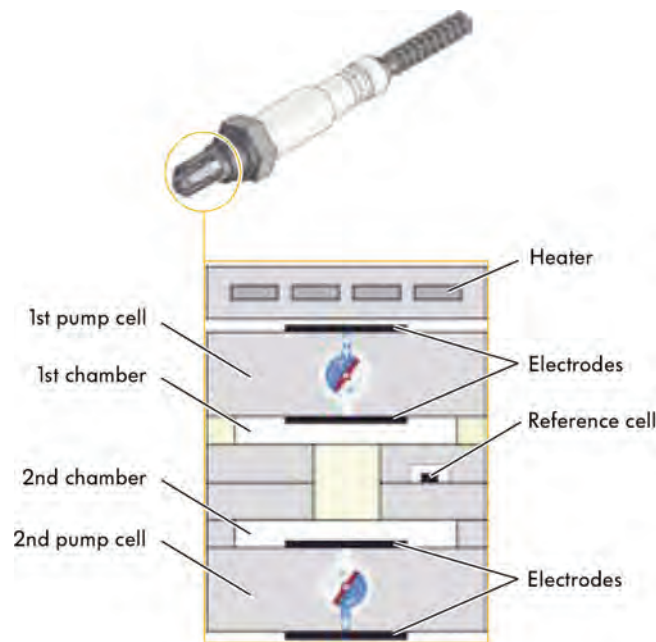
The control unit for NO_x sensor 2 regulates this voltage to a constant value. This value corresponds to an air-fuel ratio of $\lambda \approx 1$. In this case, the pump cell pumps oxygen out or in, therefore regulating the oxygen concentration in the 1st chamber to a specific value.

Function of the Second Chamber



The exhaust gas flows from the 1st into the 2nd chamber. The NO_x molecules in the exhaust gas are separated at a special electrode into N₂ and O₂. As the inner and outer electrodes are regulated to an even voltage of 400 mV, the oxygen ions migrate from the inner to the outer electrode. The oxygen pump current which flows is a measure of the nitrogen oxide content in the 2nd chamber. As the oxygen pump current is proportionate to the nitrogen oxide content in the exhaust gas, it can be used to determine the nitrogen oxide content.

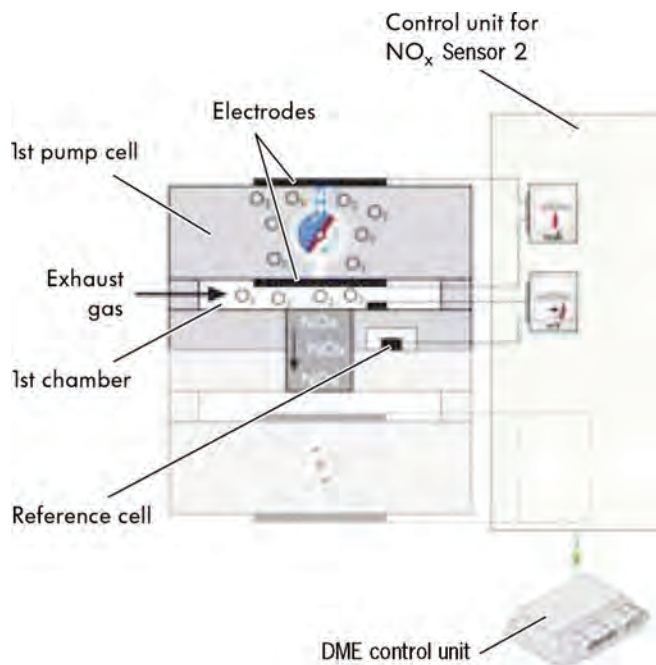
The NO_x sensor is only switched on, together with its heater, when it is ensured that no condensation is able to destroy the sensor ceramic. To achieve this, the temperature in the exhaust system must be so high that the dew point temperature of water is exceeded and that no further condensed water can be found in the sensor.



Function of the NO_x Sensor

The manner in which the NO_x sensor functions is based on oxygen measurement and can be determined from a broadband lambda probe.

Function of the First Chamber



Part of the exhaust gas flows into the 1st chamber. In the 1st chamber, the oxygen concentration is reduced to enable the low nitrogen oxide content in the exhaust gas

Fuel, Exhaust & Engine Electrical

AdBlue® Reducing Agent

The ammonia required to reduce the nitrogen oxides is not used in its pure form, but in the form of a urea solution. In its pure form, ammonia acts to irritate the skin and mucous membranes, and additionally has a penetrating odor. A fluid, which is universally referred to under its brand name, AdBlue®, throughout the automotive industry, is used as the reducing agent for the SCR system. AdBlue® is a very pure, transparent 32.5 % solution of urea in water. It is manufactured synthetically.

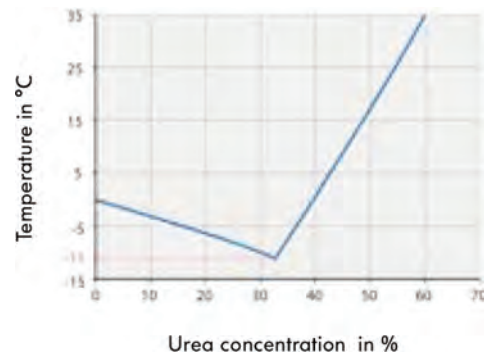
Refill Bottle for the Customer



Content: 1.89 liters (equivalent to half a gallon)

Filling concept: In order to fill the reducing agent tank, the refill bottle must be screwed onto the tank filler neck by hand. Pressing the bottle releases an opening in the adapter fitting, and the AdBlue® is able to flow into the tank. During the filling process, the gases from the tank are trapped by the refill bottle and therefore do not enter the atmosphere.

Freezing Point of AdBlue®



AdBlue® has a urea content of 32.5 % , because the reducing agent has the lowest freezing point of 12.2° F (-11° C) at this mixture ratio. Deviation from the mixture ratio due to an excessively high urea or water content causes the freezing point of AdBlue® to be raised.

Characteristics of AdBlue®

- AdBlue® freezes at temperatures below 12.2° F (-11° C).
- AdBlue® breaks down at high temperatures (approx. 158° F - 176° F/70° C - 80° C) . This results in the formation of ammonia and therefore possible odor pollution.
- Contamination with foreign substances and bacteria may render AdBlue® unusable.
- Leaked and crystalized urea causes white flecks. These flecks must be removed with water and a brush (as soon as possible).
- AdBlue® has a high creep capability. Electrical components and connectors must be protected against AdBlue® penetration.

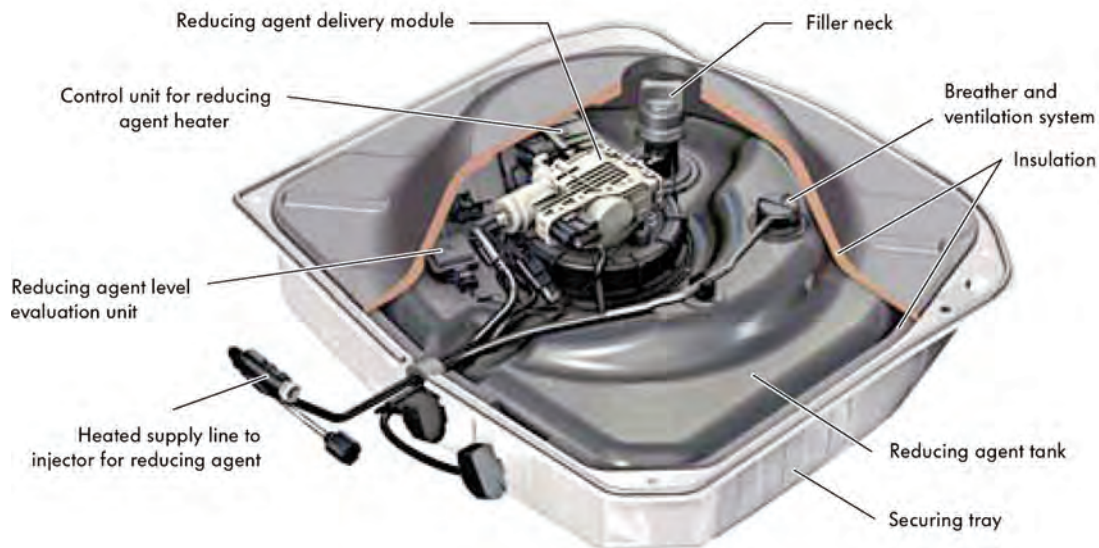


Important!

Notes on handling AdBlue®:

- Only use AdBlue® from original containers according to the manufacturer's approved standard.
- Drained AdBlue® must not be reused in order to avoid contamination.
- The reducing agent tank must only be filled using the containers and adapters approved by the manufacturer.
- The reducing agent can irritate the skin, eyes and respiratory organs. If this fluid comes into contact with skin, it should be immediately washed off with plenty of water. If necessary, seek medical advice.

Reducing Agent Tank System



The reducing agent tank is manufactured from plastic and is located beneath the spare wheel. The tank has a capacity of approx. 5.5 gallons (20.8 liter).

- Reducing agent delivery module – the delivery module contains the sensors and actuators for delivering the reducing agent in the reducing agent tank system.
- Reducing agent level evaluation unit – the evaluation unit measures the level in the reducing agent tank.
- Breather and ventilation system – the reducing agent tank system is a system which is virtually sealed from the outside. This is achieved by way of a sintered material located in the breather and ventilation system connections. Reducing agent tank pressure compensation therefore always takes place over a long period of time.

- Control unit for reducing agent heater – the control unit actuates the reducing agent tank system heaters.
- Polypropylene foam insulation – the insulation serves to protect the reducing agent from high and low ambient temperatures.

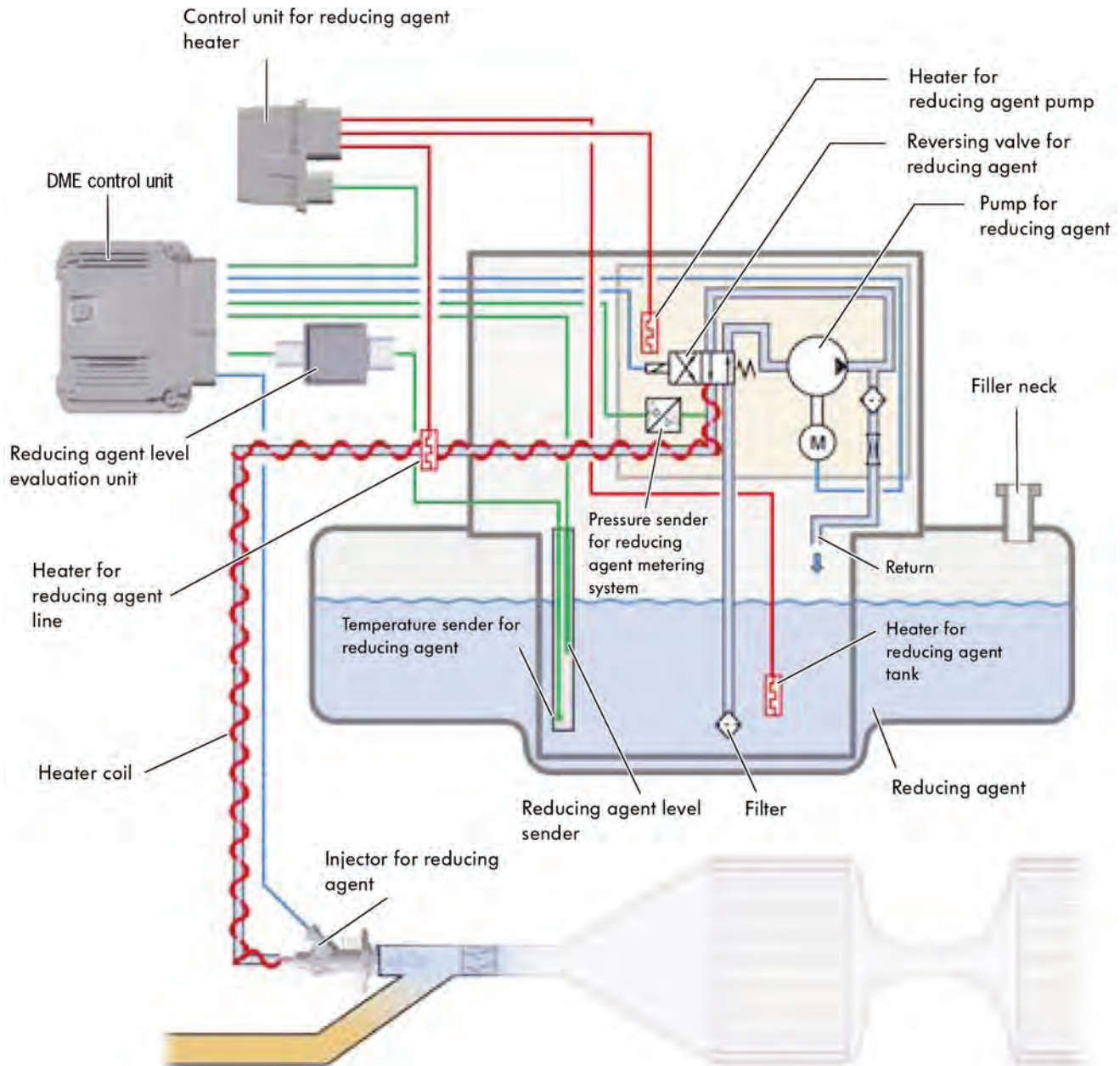
i Important!

When filling the reducing agent tank, it must be ensured that a sufficiently large expansion volume remains for the reducing agent in the tank. Only ever fill the reducing agent tank with the intended containers and filling systems. This guarantees the correct filling speed and prevents overfilling the tank. In addition, all gases from the tank are trapped in the containers and do not therefore enter the atmosphere. Never use a funnel or the like to fill the reducing agent tank, and do not independently pour reducing agent into a refill bottle for filling the tank!

Notes:

Fuel, Exhaust & Engine Electrical

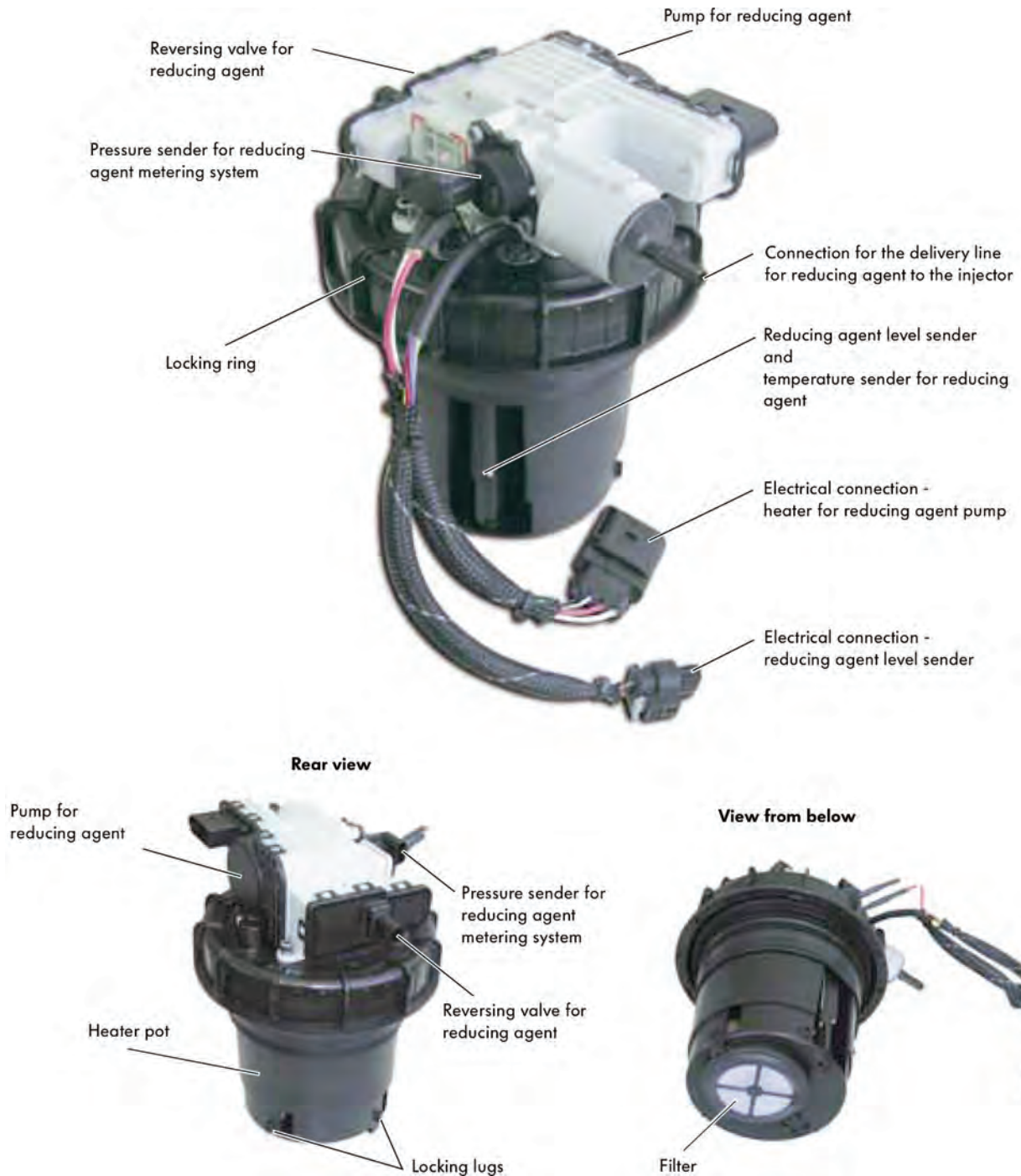
Reducing Agent Tank System Overview



Notes:

Reducing Agent Delivery Module

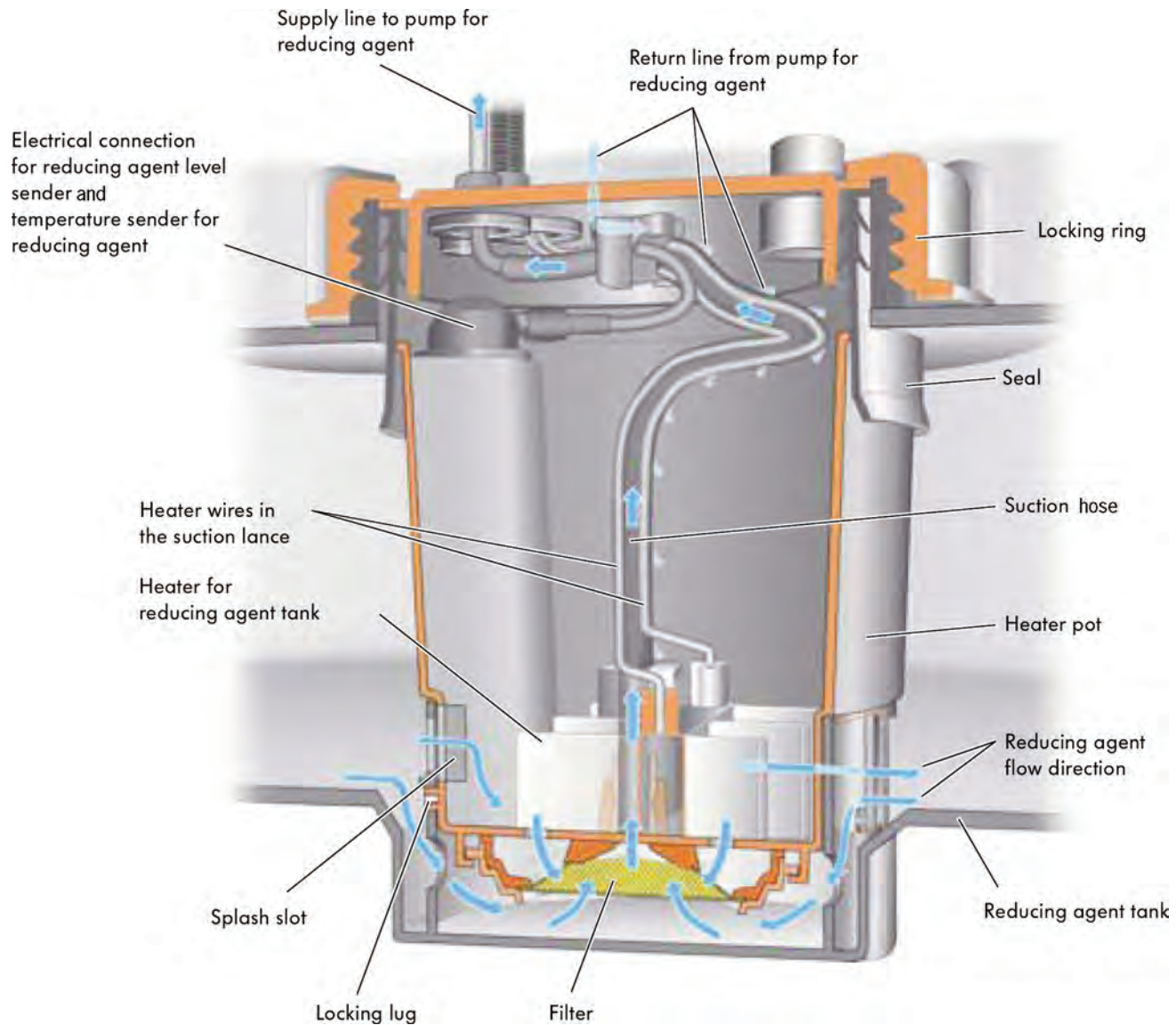
The reducing agent delivery module is secured with locking lugs in the tank and a locking ring on the upper side of the tank. The following components are integrated into the delivery module.



Fuel, Exhaust & Engine Electrical

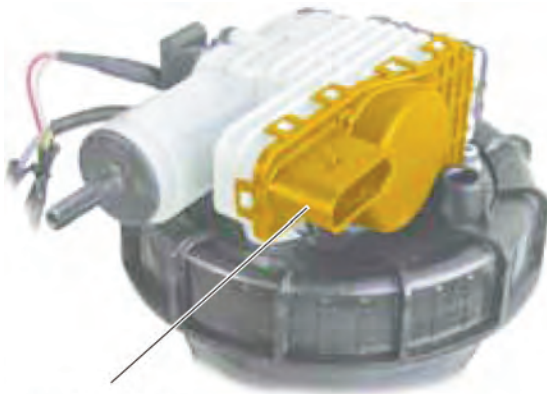
Heater Pot

The reducing agent is sucked out of what is called the heater pot via a suction hose and a filter by the reducing agent pump. The filter is intended to avoid damage to the SCR system caused by particles of dirt in the reducing agent. A heater in the heater pot ensures that SCR operation is possible even at low exterior temperatures. The reducing agent flowing back from the pump drips back into the heater pot on the outer side of the suction hose. The reducing agent enters the heater pot from the tank via splash slots. At low temperatures, the splashing motion of the reducing agent from the heater pot thaws out the frozen reducing agent in the tank.



Notes:

Pump for Reducing Agent



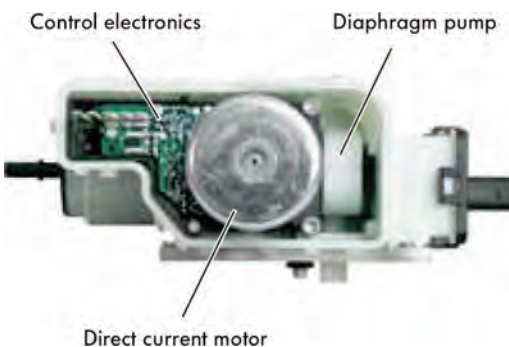
Pump for reducing agent

The pump for reducing agent is a diaphragm pump. It is driven by a brushless direct current motor. The pump for reducing agent is integrated into the delivery module housing and is actuated by the DME control unit.

Tasks

The pump for reducing agent's tasks differ depending on the position to which the reversing valve is switched:

- When the ignition is switched on and the operating conditions for the SCR system are met, the pump delivers the reducing agent from the tank to the injector at a pressure of approx. 72.5 psi (5 bar).
- When the diesel engine is switched off, it pumps the reducing agent out of the delivery line from the injector and back into the tank.



Direct current motor

The DME control unit actuates the motor with a pulse-width-modulated signal. The motor drives the diaphragm pump via a connecting rod. When the SCR system is active, the reducing agent is sucked out of the tank via the diaphragm pump and is pumped into the delivery line. If the pump for reducing agent fails, the SCR system is unable to function.

Pressure Sender for Reducing Agent Metering System

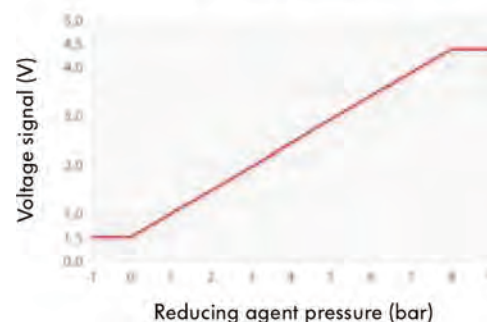


Pressure sender for reducing agent metering system

The pressure sender for reducing agent metering system is screwed into the delivery module. It determines the current for the reducing agent delivery pressure and transmits a voltage signal to the engine control unit.

Based on the signals, the DME control unit calculates the current reducing agent pressure in the line to the injector. This enables the DME control unit to regulate the pump motor's speed and therefore adapt the pump's required delivery rate.

Voltage-pressure chart
(transmission function)



If the signal from the pressure sender for reducing agent metering system fails, reducing agent metering is switched off.

Fuel, Exhaust & Engine Electrical

Reversing Valve for Reducing Agent



Reversing valve for reducing agent

The reversing valve for reducing agent is a 4/2-way directional control valve. It is integrated into the reducing agent delivery module.



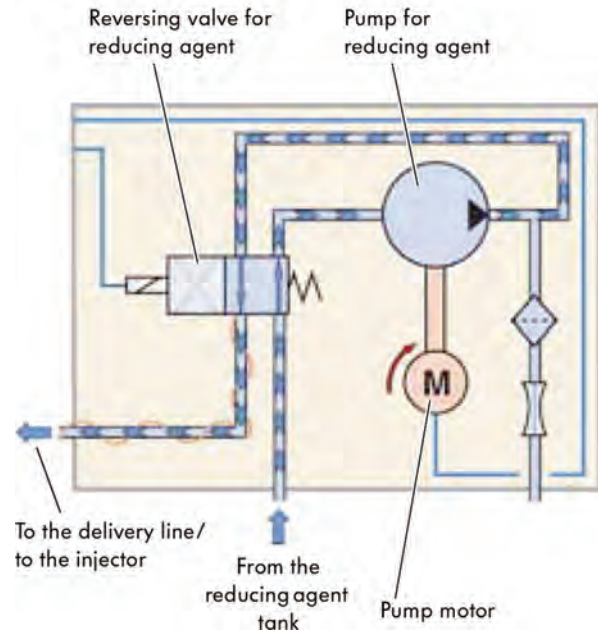
Reversing valve for reducing agent

Task

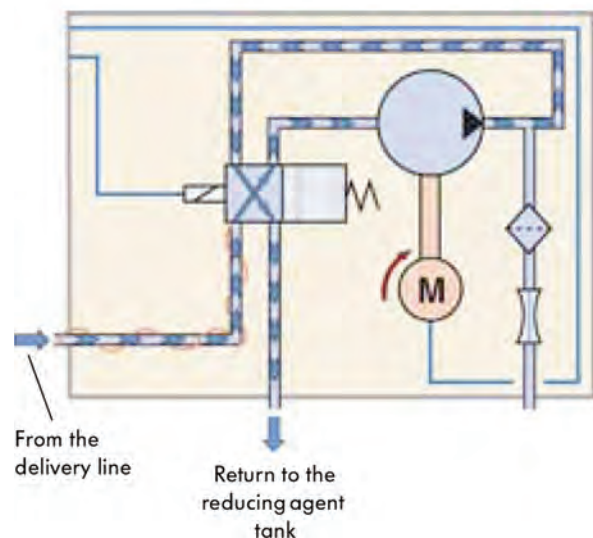
When the diesel engine is switched off, the reversing valve for reducing agent reverses the direction of reducing agent delivery. As a result, the reducing agent is returned from the delivery line to the reducing agent tank. This precautionary measure prevents the reducing agent from freezing in the delivery line and in the injector at low exterior temperatures.

When the diesel engine is switched off, the reversing valve for reducing agent reverses the direction of reducing agent flow. To achieve this, the lifting magnet is actuated via a coil. The coil is actuated by the engine control unit. Via a guide plate, the lifting magnet then switches the valve to the "emptying" position. The pump motor, which only rotates in one direction, pumps the reducing agent from the delivery line back into the reducing agent tank.

"Delivery" position



"Emptying" position

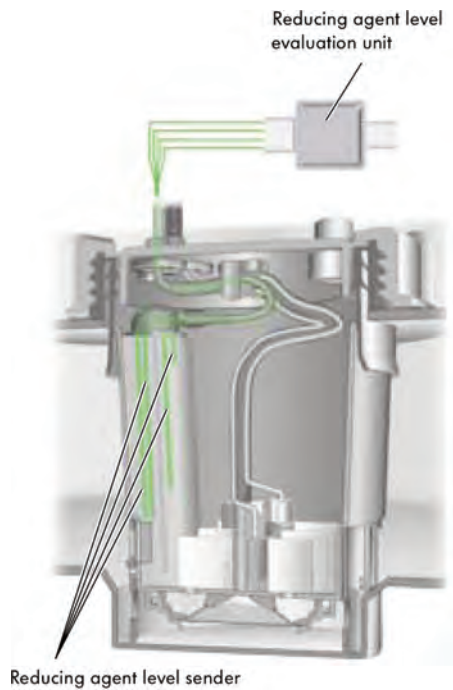


In the event that the reversing valve for reducing agent fails, the reducing agent may possibly freeze in the delivery line and in the injector at low exterior temperatures. If the valve remains in the "emptying" position, pressure build-up in the system is not possible.



The process for emptying the delivery line takes approx. 60 seconds. The vehicle battery must not be disconnected during this time, as the risk of reducing agent freezing in the delivery line at low temperatures may occur.

Reducing Agent Level Sender with Reducing Agent Level Unit



The reducing agent level sender is a sensor with 4 stainless steel level sensors. It is located directly in the heater pot. The evaluation unit evaluates the signals from the reducing agent tank sender and transmits a pulsewidth-modulated signal (PWM signal) to the DME control unit. It is secured externally, to the top of the tank.

Notes:

The evaluation unit uses the signals from the reducing agent tank sender to determine 3 different reducing agent tank levels. The 3 different measured level values are required for different display warning stages for refilling the reducing agent.

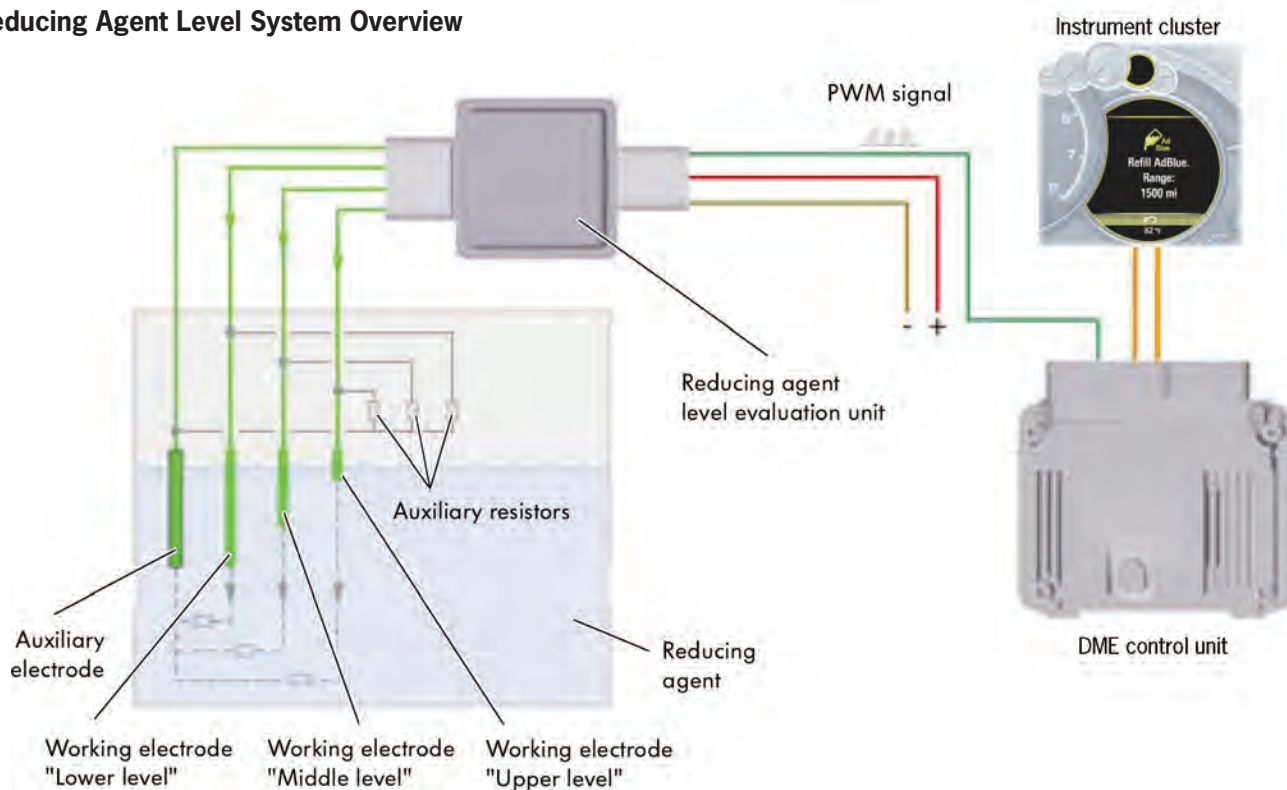
Design



The 4 stainless steel level sensors serve the evaluation unit as operating and reference electrodes.

Fuel, Exhaust & Engine Electrical

Reducing Agent Level System Overview



The electrical conductivity of the reducing agent between the fluid level sensors (working electrodes) and the reference electrode is used to determine the tank's fluid level. At short intervals, the evaluation unit applies an alternating voltage to the working electrodes and the reference electrode. An electrical current is able to flow between two fluid level sensors (working electrode and reference electrode) when both are immersed in the reducing agent. Based on the electrical conductivity, the evaluation unit determines whether the fluid level is above or below the relevant measuring sensor.

The resistance between the two measuring sensors changes due to the presence and absence of the reducing agent. This change in resistance is registered by the evaluation unit and is processed as a signal for the engine control unit. "Splash conditions" are electronically "dampened" by the evaluation unit. Refilling is detected by the system after a delay due to the "electronic damping". In order to point out to the driver that reducing agent should be replenished in the event of low fluid levels, the engine control unit transmits a signal to the control unit in instrument cluster.

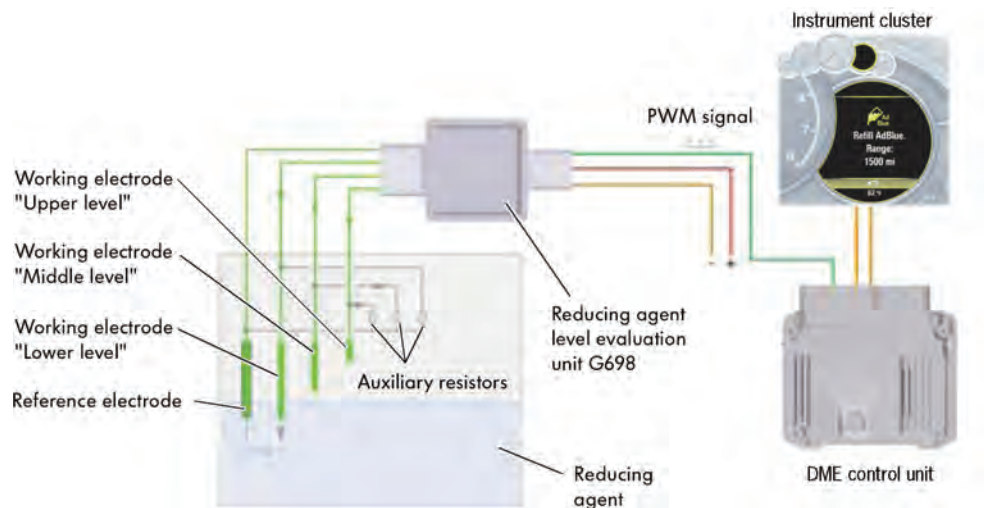
Example of a Warning for a Declining Fluid Level

If the fluid level falls below the "middle level" measuring sensor, the current between the "middle level" working electrode and the reference electrode no longer flows via the reducing agent medium but via the auxiliary resistor belonging to the "middle level" working electrode. The current also flows via the relevant auxiliary resistor in the case of the "upper level" working electrode. The current flows via the reducing agent in the case of the "lower level" working electrode. The auxiliary resistor's resistance is many times higher than that of the reducing agent. From this changed resistance value, the evaluation unit recognizes that the fluid level has fallen below this level. This signal is processed by the evaluation unit and transmitted to the DME control unit.

In order to notify the driver that reducing agent should be replenished in the case of this level, the DME control unit transmits a signal to the instrument cluster. In the dash panel insert display, the driver is requested to fill up with fluid via a warning lamp. The remaining range is calculated by the DMW control unit from the mean reducing agent consumption volume and the residual reducing agent volume.

Reducing Agent Level System Overview

The auxiliary resistors also serve to diagnose open circuits and to check plausibility. The measuring principle does not function in the case of frozen reducing agent, as no reliable resistance value can then be determined. If the tank sender signal fails, the reducing agent tank's fluid level cannot be registered. However, the SCR system remains active.



AdBlue® Display in the Instrument Cluster

The AdBlue® display is located in the instrument cluster. It lights up to notify the driver to replenish the reducing agent at an early stage or to indicate a system fault.



Initial warning illuminates with a range of 1,500 miles. Acoustic warning signal (1 gong) sounds as additional indication



Second warning illuminates with a range of 600 miles. Driver is also warned that the **engine will not start** if it has been switched off after covering the remaining distance. Acoustic warning signal (1 buzzer) sounds as additional indication



Indication appears when there is no reducing agent in the tank. Driver is informed that **engine start not possible**. Three successive acoustic warning signal (buzzer) sounds are sounded as additional indication.

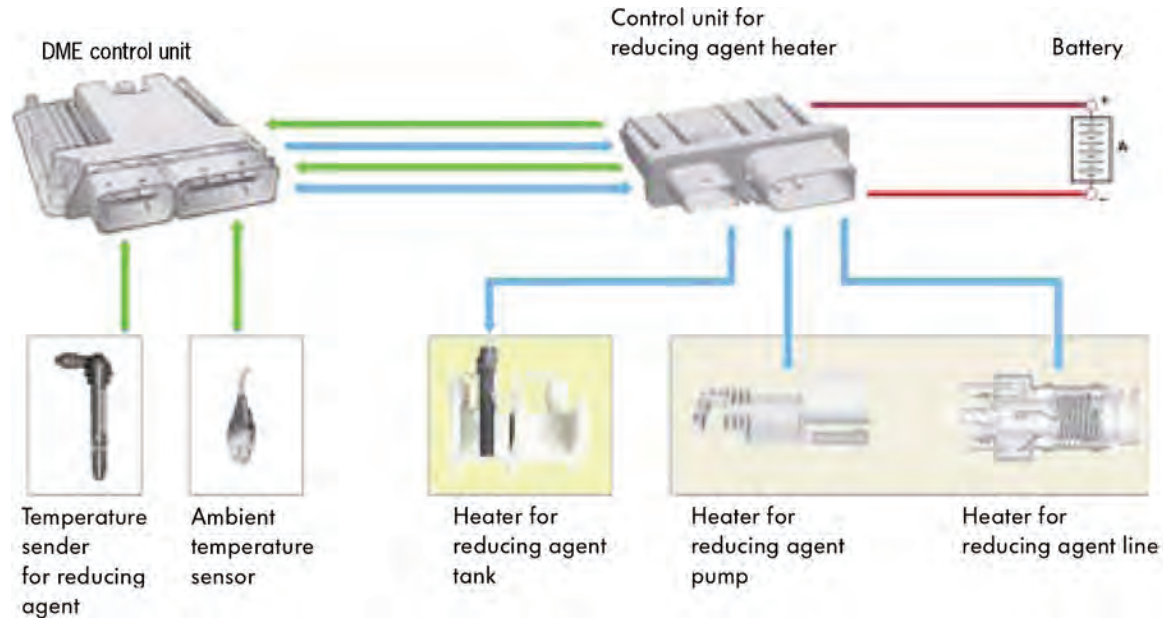
When the minimum AdBlue® fluid level has been reached, at least 5 qts (5.0 liters) have to be added in. This corresponds to approximately three of the commercially available refill bottles. Only this refill quantity guarantees that replenishing is recognized and that starting the engine is therefore possible again.



Indication appears if there is a fault in the AdBlue system

Fuel, Exhaust & Engine Electrical

Reducing Agent Heater System Overview



Reducing Agent Heater System

Due to the possibility of the reducing agent's freezing at low exterior temperatures, the reducing agent tank, the pump for reducing agent and the line to the injector are each equipped with a heater. The heater system enables rapid SCR system operational readiness in the event of frozen reducing agent and ensures an adequate quantity of thawed reducing agent at all operating points.

Control Unit for Reducing Agent Heater



The control unit for reducing agent heater controls the electrical power supply for the SCR system's heaters. It is located on the upper side of the reducing agent tank and is actuated by the DME control unit.

The DME control unit recognizes the reducing agent's heating requirements from the information provided by the ambient temperature sensor and the temperature sender for reducing agent. It then actuates the control unit for reducing agent heater, which activates the electrical power supply for the heaters. The engine control unit receives feedback regarding the heater current actually flowing from the control unit for reducing agent heater.

The control unit for reducing agent heater activates the SCR system's heaters. The heater control system is subdivided into two heater circuits. If the control unit for reducing agent heater fails, the reducing agent may freeze at low exterior temperatures.

	Heater Circuit 1	Heater Circuit 2
Activation	If the temperatures in the tank or in the ambient air are less than 19.4° F (−7° C), the heater for reducing agent tank is activated via the control unit for reducing agent heater by the DME control unit.	If the temperatures in the ambient air are less than 23° F (−5° C), the heater for pump for reducing agent and the heater for reducing agent line are activated via the control unit for reducing agent heater by the DME control unit.
Heating period for thawing	At temperatures from 19.4° F to 8.6° F (−7° C to −13° C), the heating period is approx. 20 minutes. At temperatures of −13° F (−25° C) and below, the heating period may increase up to 45 minutes. In this case, the reducing agent is actively thawed in order to attain metering readiness for the system.	At temperatures below −23° F (−5° C), the heating period is approx. 100 seconds, increasing to 21 minutes at temperatures of −13° F (−25° C).
Readiness heating	At temperatures below 19.4° F (−7° C), the heating period for thawing is always followed by readiness heating. This takes approx. 5 minutes. Readiness heating serves to ensure that an adequate quantity of thawed reducing agent is provided at all operating points.	

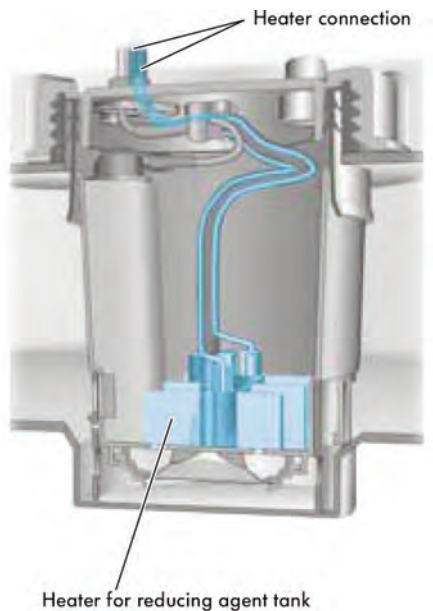
Notes:

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slight shadow on its right side, suggesting it's resting on a surface.

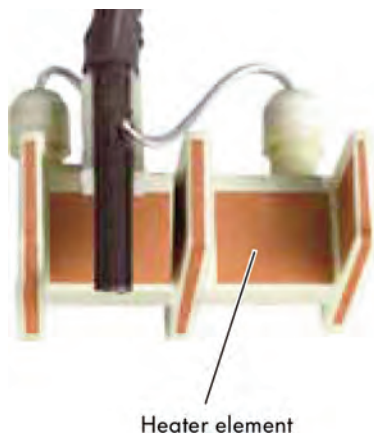
Fuel, Exhaust & Engine Electrical

Heater for Reducing Agent Tank

The heater for reducing agent tank is a heater element with a PTC resistor. PTC resistors have their highest conductivity or lowest resistance when cold. They have a positive temperature coefficient (PTC). This means that their resistance increases as the temperature rises, leading to a reduction in the flow of current. The heater element is cast in plastic and is located directly in the reducing agent tank's heater pot. The heater is actuated by the DME control unit via the final output stage.



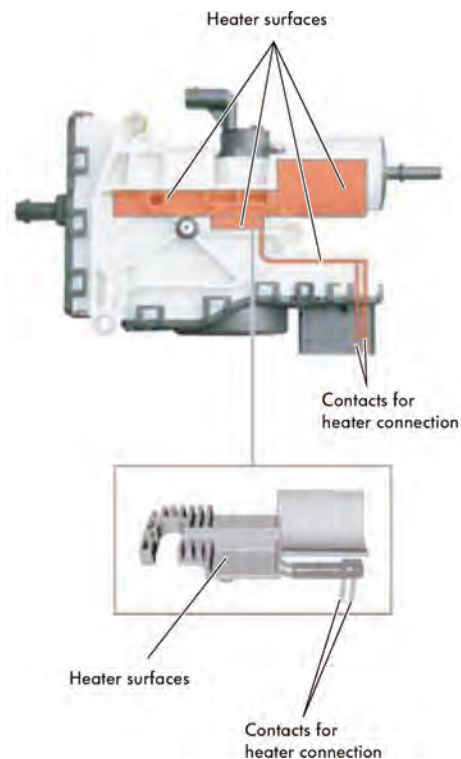
The heater for reducing agent tank has the task of heating the reducing agent in the heater pot in the case of low exterior temperatures or low temperatures in the reducing agent tank, in order to enable metering readiness for the SCR system in a short amount of time.



If the temperatures in the tank or in the ambient air are less than 19.4° F (–7° C), the heater for reducing agent tank is activated via the reducing agent heater control unit by the DME control unit. If the control unit for reducing agent heater fails, the reducing agent may freeze at low exterior temperatures.

Heater for Reducing Agent Pump

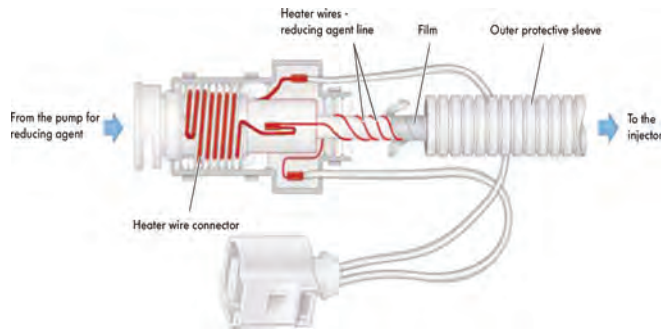
The heater for the pump for reducing agent is also a heater element with a PTC resistor. The heater element is cast into the delivery module and is located in the area of the pump for reducing agent, the reversing valve and the connection to the delivery line. The heater for the pump for reducing agent is actuated by the DME control unit via the reducing agent heater control unit.



The heater for the pump for reducing agent has the task of heating the reducing agent in the area of the pump for reducing agent, the reversing valve and the connection to the delivery line in the event of low exterior temperatures. This ensures reliable SCR system operation even at low exterior temperatures. If the temperature of the ambient air is less than 23° F (–5° C), the heater for the pump for reducing agent is activated via the reducing agent heater control unit by the DME control unit. If the control unit for the reducing agent heater fails, the reducing agent may freeze at low exterior temperatures.

Heater for Reducing Agent Line

The heater for the reducing agent line is a stainless steel resistor wire. The resistor wire is wound around the delivery line and is protected from the outside by a plastic tube. The heater for the reducing agent line is actuated by the DME control unit via the control unit for reducing agent heater.



The heater for the reducing agent line has the task of heating the reducing agent in the delivery line to the injector in the event of low exterior temperatures. This ensures reliable SCR system operation even at low exterior temperatures.

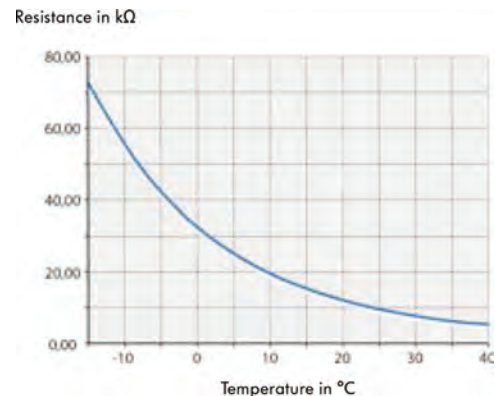
If the temperature of the ambient air is less than 23° F (–5° C), the heater current for the heater for the reducing agent line is activated via the control unit for reducing agent heater by the DME control unit. If the control unit for the reducing agent heater fails, the reducing agent may freeze at low exterior temperatures.

Temperature Sender for Reducing Agent

The temperature sender for the reducing agent is a sensor with a negative temperature coefficient (NTC). It is located in the housing of the reducing agent tank sender and measures the temperature of the reducing agent in the heater pot.



The DME control unit uses the signal from the reducing agent temperature sender to switch on the heater for the reducing agent tank and the heater for pump for reducing agent.



The temperature sender is a resistor wire with a negative temperature coefficient (NTC). This means that the sensor's electrical resistance decreases as the temperature of the reducing agent increases. The DME control unit uses the resistance signal to calculate the current temperature of the reducing agent.

Fuel, Exhaust & Engine Electrical

System Overview of the DME Control Unit

